



**White Paper
Blu-ray Disc™
Read-Only Format
(Ultra HD Blu-ray™)**

**Audio Visual Application
Format Specifications
for BD-ROM Version 3.1**

August 2016

White Paper Blu-ray Disc™ Read-Only Format

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Blu-ray Disc Association

4444 Riverside Dr. Suite 103
Burbank, CA 91505, U.S.A.

Fax.: +1-818-557-1674
Web Site: <http://www.blu-raydisc.info>
E-mail: agent@blu-raydisc.info

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1 Foreword

The Blu-ray Disc format has been the highest quality option for distribution of High Definition Video Content for nearly a decade. Recently, several key factors have impacted the television entertainment market, including the emergence of new screen technologies such as larger, brighter, and more colorful displays with resolutions up to UHD.

The Blu-ray Disc Association (BDA) gathered industry professionals from the Consumer Electronics Industries, Information Technology Companies, and Studio Content Providers to propose an extension to the Blu-ray Disc format.

BDA has developed a new, next generation format extension that addresses many of these new display capabilities and leverages Blu-ray Disc's capacity and high data transfer rates to deliver pristine UHD resolution picture with a significantly extended color gamut, high dynamic range (HDR) and other features designed to sustain the Ultra HD Blu-ray format as the unparalleled and consistent platform for the highest possible quality motion picture and sound distribution to the consumer for the foreseeable future.

This document describes the overview of Ultra HD Blu-ray format "System Description Blu-ray Disc Read-Only Format Part3: Audio Visual Basic Specifications Version 3.1" (hereafter Ultra HD Blu-ray or BD-ROM Part3 V3.1) by referring to the Blu-ray Disc format "System Description Blu-ray Disc Read-Only Format Part3: Audio Visual Basic Specifications Version 2.5" (hereafter BD-ROM Part3 V2.5) and its White Paper.

2 Overview of Ultra HD Blu-ray™ format

Ultra HD Blu-ray format has been developed to enable unparalleled UHD experience based upon the Blu-ray Disc format. Following figure shows the high level relationship between Ultra HD Blu-ray format (BD-ROM Part3 V3.1) and the Blu-ray Disc formats (BD-ROM Part3 V2.5 for 2D and BD-ROM Part3 V2.5).

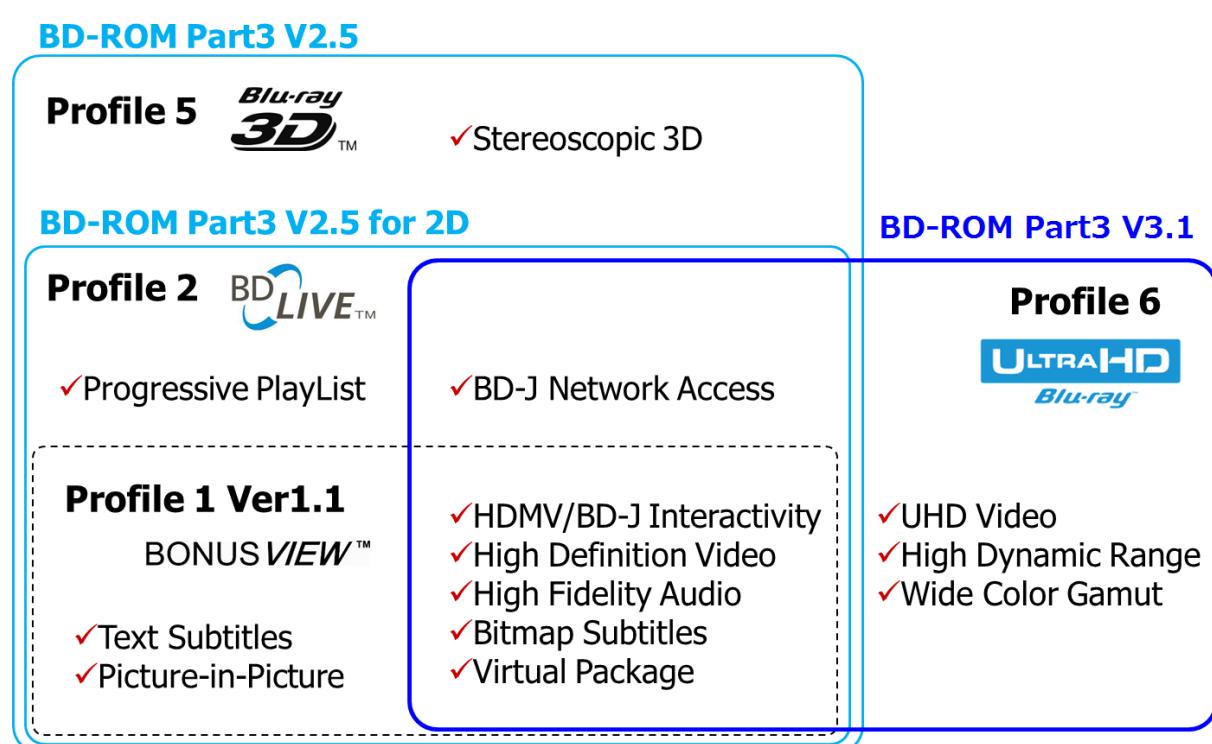


Figure 2-1 – Relationship between BD-ROM Part3 Specifications

Note: Overview of the Blu-ray Disc formats is available in other White Papers.
<http://www.blu-raydisc.com/en/Technical/TechnicalWhitePapers/BDROM.aspx>

Following sections provide technical specifications and features of Ultra HD Blu-ray format.

2.1 Introduction

For the purpose of providing the reader with an understanding of BD-ROM features, this section categorizes related features into “modes” of which two are defined (“HDMV” and “BD-J”). The categorization used in this section does not represent the actual structure of BD-ROM nor does this section provide a description of the complete set of features supported by Ultra HD Blu-ray format.

2.1.1 Introduction to HDMV mode

Ultra HD Blu-ray format provides an easy-to-author framework for creation of High Definition (HD) and/or Ultra High Definition (UHD) movie experiences known as “HDMV” (High Definition Movie) mode. HDMV supports a lot of features such as multi-angle and multi story, Language Credits (dynamic selection of a credits sequence depending on the users Language choice), Director’s cuts, Trilogy collections etc.

Here are some of the key features offered by HDMV:

- Industry Standard High Definition Video and Surround Sound Audio:
 - MPEG-4 AVC and HEVC video formats.
 - LPCM as well as Dolby® Digital, Dolby Digital Plus, Dolby Lossless, DTS digital surround®, DTS-HD®, DRA and DRA Extension audio formats.
- Audio mixing:
 - Interactive audio can be mixed with the Primary audio.
- Independent High Definition Graphic planes:
 - Two independent High Definition graphic planes and one High Definition or Ultra High Definition video plane simplifies the process of Authoring both Menu and Subtitle graphics.
- Menu features:
 - “Multi-page Menus” - Menu presentations can be changed with no interruption to AV playback.
 - “Pop-up Menus” – Menus can be shown or removed from display based on User request.
 - Full color High Definition animated Buttons and animated Menu transition effects.
 - “Button-sounds” – sounds can be presented when Menu Buttons are selected or activated.
- Subtitle features:
 - High Definition “Bitmap Subtitles” supporting full color images with frame-accurate animation effects up to 30Hz.

Details of the HDMV platform are given in Section 2.2 along with more detailed examples of HDMV applications.

2.1.2 Introduction to BD-J mode

BD-ROM also provides a fully programmable application environment with network connectivity thereby enabling the Content Provider to create highly interactive, updateable BD-ROM titles. This mode is based on the Java™ platform and is known as “BD-J”. Content Providers are able to include interactive Java applications on a BD-ROM disc in various ways (one application for the entire disc, one application per Title, etc.).

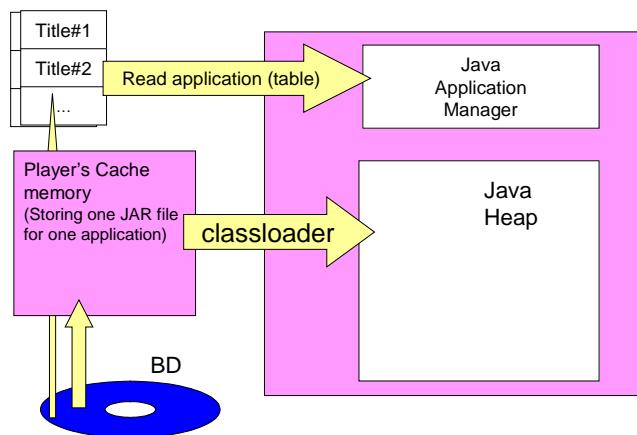


Figure 2-2 – Overview of Java application tables in BD-ROM

Possible BD-J applications include:

- A BD-ROM Title that supports downloading trailers for a sequel from a Content Provider's website and playback under application control.
- A BD-ROM disc with a set of games, each game associated with a Title in the disc's table of content. The main Menu of the disc allows downloading subsequent games from a Content Provider's website under certain conditions, like solving a puzzle for example.
- A BD-ROM Title is distributed supporting only a small number of languages. Later support for more languages (i.e. subtitle and or audio streams) can be downloaded by the BD-J application on the disc.

Java is a platform independent programming environment deployed in a wide variety of environments: Server based applications can be supported through the Java 2 platform Enterprise Edition (J2EE), while Desktop based applications can be supported through the Java 2 platform Standard Edition (J2SE), and Consumer Electronics based applications (for devices like cell-phones and interactive digital receivers) can be supported through the Java 2 platform Micro Edition (J2ME). Java provides an open and flexible programming environment for BD-ROM.

BD-J provides a Java UI & graphics framework along with support for Local Storage and Internet connectivity features thereby creating a complete and future proof solution. A BD-ROM disc can contain a mix of titles based on HDMV and BD-J. Details of the BD-J platform are given in Section 2.3 along with more detailed examples of BD-J applications.

2.1.3 Player profile

In the BD-ROM Part3 V3.1, only one Profile (Profile 6) is defined. Other Profiles are reserved for other formats. Profile 6 has been designed based upon Profile 5 incorporating UHD (Ultra High Definition), HDR (High Dynamic Range) video and a new video codec (HEVC) and excluding some Profile 2 or Profile 5 features, e.g., S3D (Stereoscopic 3D), Picture-in-Picture, audio mixing with Secondary Audio and Progressive Playlist.

2.2 Application Concepts of HD movie mode functions

The BD-ROM HDMV platform provides a flexible, simple framework for creation of interactive High Definition and Ultra High Definition movie experience applications. This Section will provide an overview of some of the key features provided in HDMV.

2.2.1 Core functions

2.2.1.1 Out-of-Mux stream Framework

HDMV provides a framework for individual stream handling. An Out-of-Mux stream is an additional stream which is decoded while the main MPEG-2 transport stream is decoding. The Out-of-Mux framework provides support for applications such as Pop-Up Menus and additional Primary audio/Subtitle playback.

2.2.1.1.1 Decoder model

The HDMV decoder model is equipped with two read buffers, two preloading buffers and switches. The second read buffer (RB2) enables the supply of an Out-of-Mux audio, Presentation Graphics (PG) and Interactive Graphics (IG) stream to the decoders even while the main MPEG-2 transport stream is being decoded. The preloading buffers cache Interactive Graphics and sounds effects (which are presented at Button selection or activation). The preloading buffers store data before movie playback begins and supplies data for presentation even while the main MPEG-2 transport stream is being decoded.

The switch before the buffers selects the appropriate buffer to receive demodulated packet data from the BD-ROM Drive or Local Storage. Before starting the main movie presentation, effect sounds data (if it exists) and Interactive Graphics (if preloaded Interactive Graphics exist) are preloaded and sent to each buffer respectively through the switch. The main MPEG-2 transport stream is sent to the primary read buffer (RB1) and the Out-of-Mux stream is sent to the secondary read buffer (RB2) respectively by the switch.

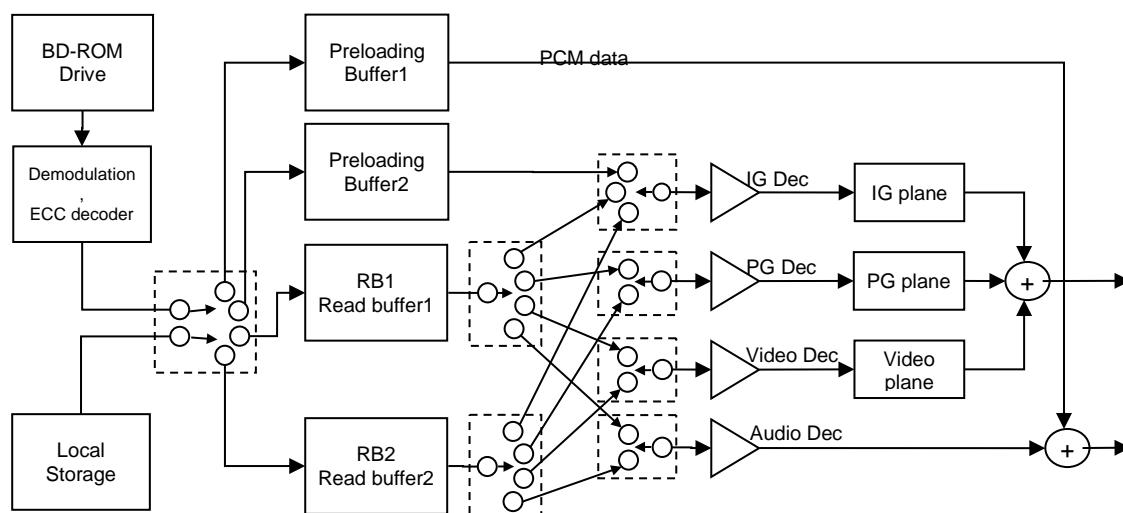


Figure 2-3 – Decoder model

2.2.1.2 Graphics Framework

HDMV provides two graphics frameworks for compositing graphics on video: the Interactive Graphics system and the Presentation Graphics system.

A BD-ROM Interactive Graphics stream contains information required to provide a series of interactive displays, which appear and disappear with frame accuracy, that are supplemental to an associated HDMV presentation. Interactive Graphics streams are typically used to provide both the display and associated commands of graphical interactive menus during a HDMV presentation.

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A BD-ROM Presentation Graphics stream, available in both HDMV and BD-J modes, contains information required to provide non-interactive images that are supplemental to an associated BD-ROM presentation. The images described in the stream are designed for graphic overlay, with frame accuracy, on the associated video image. BD-ROM Presentation Graphics streams are typically used to provide subtitle services and/or other animated graphics during a HDMV or BD-J presentation.

2.2.1.2.1 Graphics planes

As shown in Figure 2-4, HDMV defines two independent full HD resolution (1920x1080) graphics planes for graphics which are composited on the video plane. One graphics plane is assigned for subtitling applications (Presentation Graphics) and the other plane is assigned to interactive applications (Interactive Graphics). When Graphics planes are used during 3840x2160 video playback, BD-ROM player upscales the 1920x1080 Graphics planes to 3840x2160 before overlaying process.

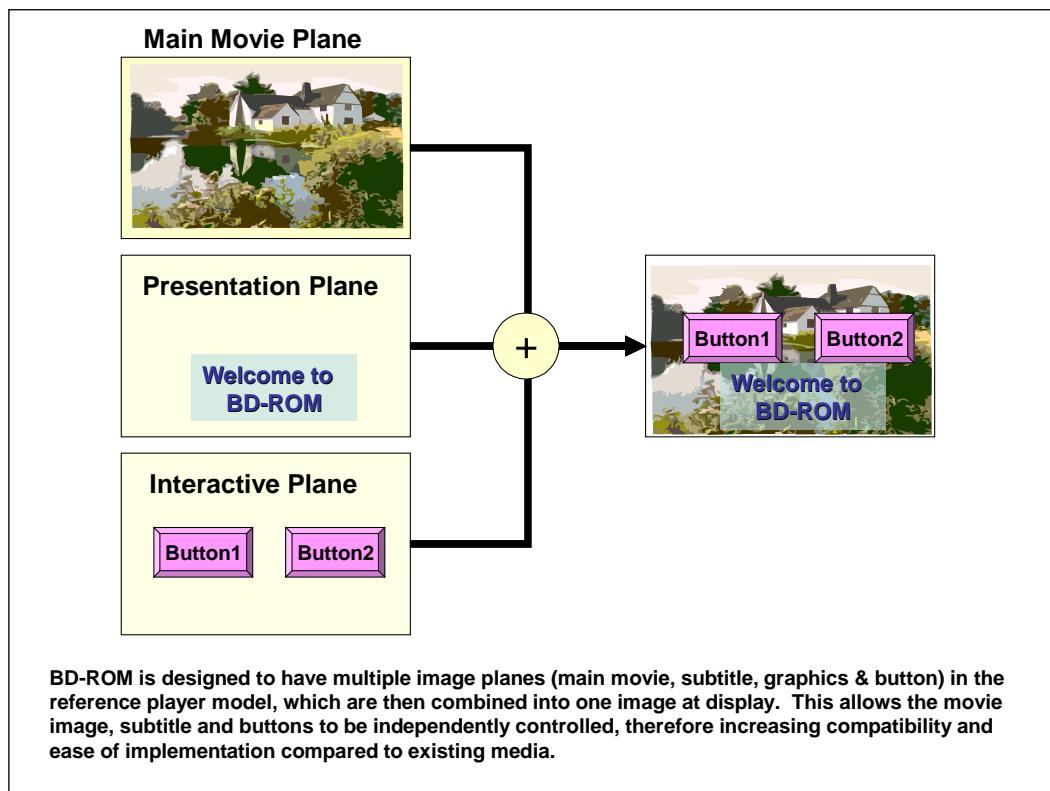


Figure 2-4 – Graphics planes

Each graphics plane has 8-bits per pixel, with each pixel value referring to an index entry in a Palette for translation to YCrCb color and 8-bit (256 level) alpha. This color capability offers an enhanced visual experience and allows compelling content to be displayed using the HDMV Interactive Graphics system.

2.2.1.2.2 Graphics model

The HDMV graphics systems define a flexible decoding and composition system for providing graphics displays whereby graphic images may be reused, with different effects applied, in one or more graphics displays.

A HDMV graphics stream consists of one or more “Segments” – “Segments” are the basic syntactical element of HDMV graphics streams. The three most important types of Segments are - Graphics Object Segment, Composition Segment and Palette Segment:

- Composition Segment – defines the appearance of a graphics display.
- Graphics Object Segment – Bitmap image data compressed with an RLE compression schema.
- Palette Segment – color and transparency data (up to 256 entries) for translation of 8bit index color to full color when compositing on the video plane.

Segments are processed by the BD-ROM HDMV graphics decoder as shown in Figure 2-5 below.

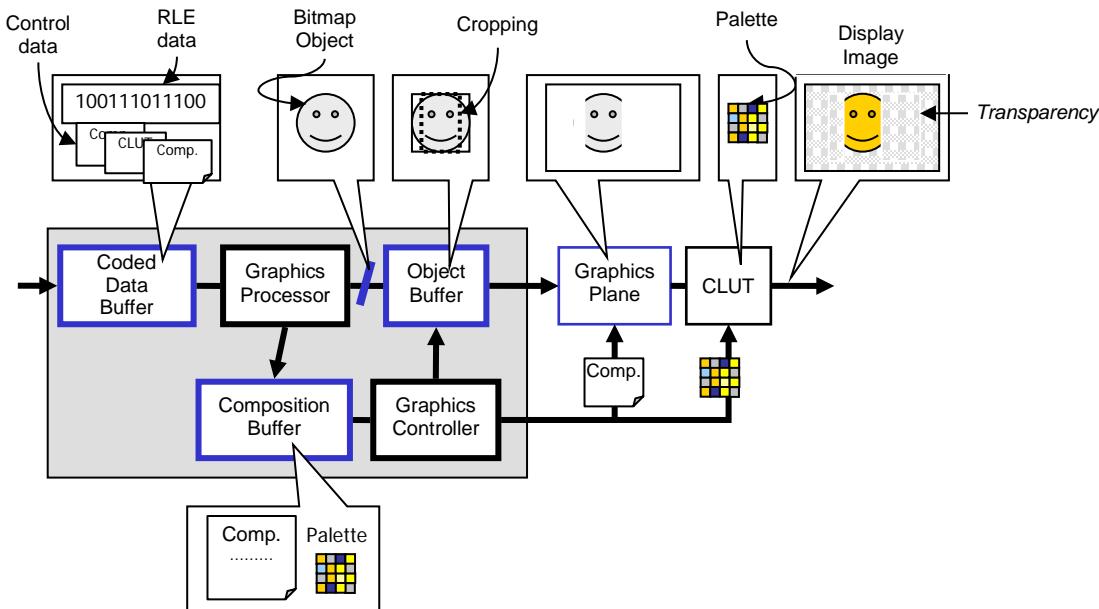


Figure 2-5 – Illustration of BD-ROM HDMV Graphics decoding

A Segment first arrives at the Coded Data Buffer. The Graphics Processor extracts the Segment at the time defined by a system time-stamp associated with the Segment. When Composition and Palette Segments arrive at the Graphics processor, they are decoded to the Composition Buffer.

When Graphics Object Segments arrive at the Graphics Processor, the Graphics Processor decodes the Graphics Object to an uncompressed 8-bit graphics object which is then stored in the Object Buffer. Once a Graphics Object has been decoded, it is available for use by one or more graphics displays as described in Composition Segment.

The Graphics Controller is responsible for compositing graphics images on to the graphics plane in accordance with the description in the Composition Segment. The composited image on the graphics plane is transformed to full color and transparency by the CLUT module and then overlaid on the video image. The decoder implements a Pipelined decoding model such that Graphics Displays may be assembled in the Graphics Plane while, at the same time, new Graphics data is decoded into the Object Buffer.

2.2.1.2.3 Graphics animations

Support for graphics effects is part of the graphics tool set for Content Providers to create rich BD-ROM Graphics Displays. Supported effects include scrolls, wipes, cuts, fades (transparency changes) and color changes. All of these effects may be utilized in both Interactive (e.g. to be used for Menu page transitions) and Presentation Graphics streams (e.g. to be used for advanced Subtitles or Karaoke).

Composition Segments indicate the Graphics Objects to be used for a graphics display and may define a cropping transform to be applied when compositing the Graphics Object. Composition Segments also indicate the Palette to be used for the graphics display. Effects are realized by providing multiple Compositions Segments which change cropping areas of Graphics Objects (e.g. to

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provide wipes, scrolls and cuts) as illustrated in Figure 2-6 and/or reference different Palettes (e.g. to provide fades or color changes).

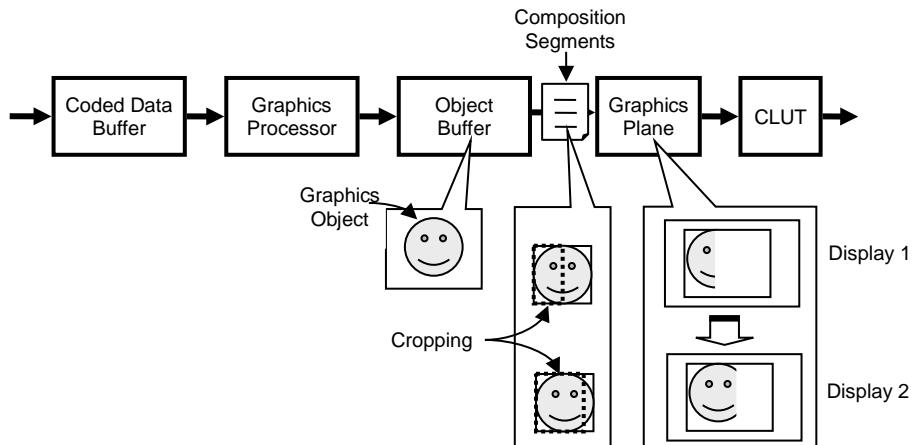


Figure 2-6 – Illustration of wipe effect

HDMV Interactive Graphics are further extended to support animated sequences of graphics for Buttons. The Normal, Selected and Activated states of a Button may be animated with a sequence of different images. With 8-bit index color and transparency support along with support for frame-rates up to 30Hz, the creative possibilities are greatly expanded over existing formats.

2.2.1.3 Text Subtitle Framework

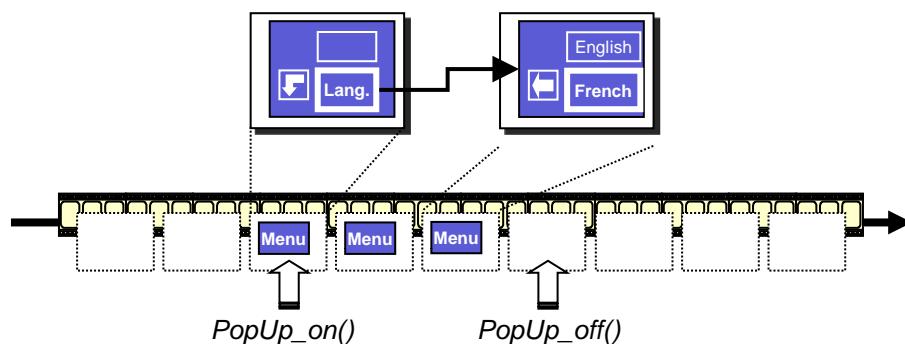
This format does not provide support for Text based subtitles.

2.2.1.4 Interactivity Framework

2.2.1.4.1 Pop-Up Menus

HDMV Interactive Graphics support a “Pop-Up” Menu Interface: once playback of video has begun, HDMV graphical interactive content may be activated during the playback of video by pressing a ‘Pop-Up’ Button on the remote. In this case, video playback can continue while the HDMV Interactive Graphics are on the screen or video playback may be put into still mode – this is determined by the Content Provider using navigation commands.

Menus that support a “Pop-Up” Menu Interface are always pre-loaded. As shown in Figure 2-10, several pages of HDMV Interactive Graphics data can be pre-loaded before playback starts. This Interactive Graphics data is kept in memory during playback of the AV stream and is not displayed until requested by the user.



2.2.1.4.2 Always-On Menus

HDMV Interactive Graphics support an “Always-On” Menu Interface; Interactive Graphics content that cannot be removed from the screen by user request is called “Always-On”. This is one of the methods provided by HDMV to present interactivity to the user. For example, a Menu implemented with the Always-On interface may be presented to the user when the disc is inserted into the BD-ROM Player.

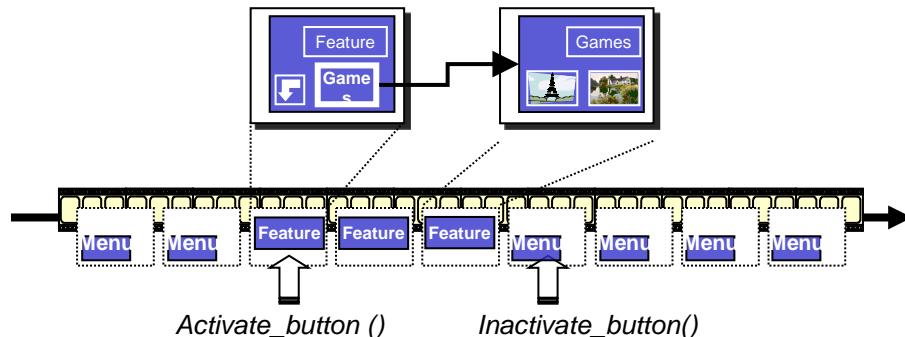


Figure 2-11 – Illustration of Always-On Menus

Menus that support an “Always-On” Menu Interface may be pre-loaded or multiplexed with video. If the HDMV Interactive Graphics stream is multiplexed with video, PTS/DTS timestamps can frame accurately determine when the Always-On Menu shall appear and disappear.

2.2.1.4.3 Multi-page Menus

The HDMV Interactive Graphics framework provides a scheme for Menu Page definition, thereby allowing a large amount of data to be presented in an organized manner with special commands available for inter-page navigation. When a Button is activated, a corresponding navigation command is executed which causes the display to change to a specified page. This action is performed with no visible interruption to the screen allowing a seamless user experience.

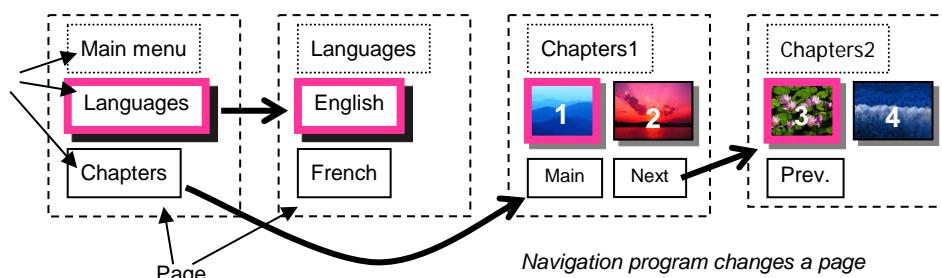


Figure 2-12 – Example of Multi-page Menu

2.2.1.4.4 Button enabling and disabling

The HDMV Interactive Graphics framework also provides a scheme for dynamic graphics display. On a single page, this enables the Content Provider to determine dynamically which Buttons are visible and invisible at any point in time. This scheme could be used, for example, to provide Buttons that present a set of options and when one of those Buttons is selected, additional Buttons appear. When a Button is enabled it becomes visible and can be navigated to. This action is performed with no visible interruption to the screen allowing a seamless user experience. The Content Provider may choose to either keep the earlier Buttons accessible or disable them which would clear them from the display.

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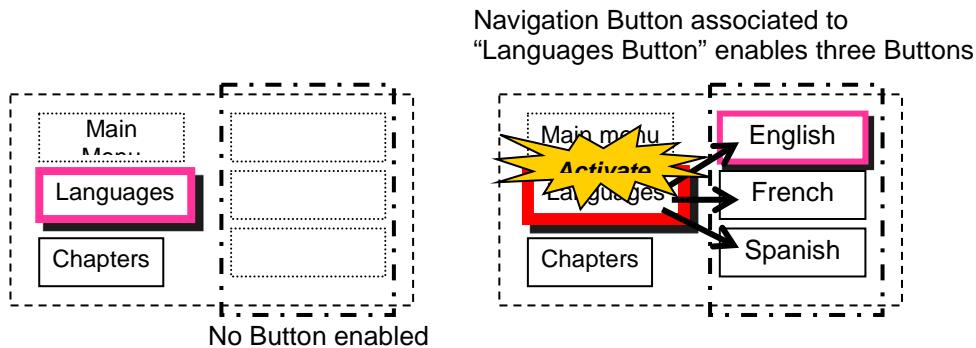


Figure 2-13 – Example of Button enabling and disabling

2.2.1.5 Command Framework

HDMV provides a simple programming platform to enable the Content Provider to author interactive movie contents. This platform provides a scheme to manage the behavior of menus, playback and so on.

There are two types of Objects which contain navigation commands – the Movie Object and the Button Object. A Movie Object is executed when the Title associated with the Movie Object begins playback. Movie Object navigation commands are used to manage PlayList playback. While a PlayList is under playback, the state of a Movie Object is maintained and resumes after PlayList playback is terminated. A Button Object is an alternative programming method that is available while the PlayList is under playback and a Button Object is executed by user activation or system timer.

2.2.1.5.1 Programming commands and Registers

HDMV navigation commands have three operation groups: playback operation group, compare operation group, and arithmetical and bitwise operation group. The playback operation group manages PlayList playback, execution of Movie Objects, execution of Titles and control of the Graphics display (Button enabling and disabling). The comparison operation group provides comparison functions between parameters and/or given values and provides a Boolean result.

The BD-ROM Player has two types of Registers: General Purpose Registers and Player Status Registers. General Purpose Registers provide the Content Provider with 4096 4-bytes unsigned registers. Player Status Registers represent the BD-ROM Player's playback status, configuration and preferences.

2.2.1.5.2 Picture-in-Picture framework

This format does not provide support for Picture-in-Picture framework.

2.2 Application Examples

2.2.2 Interactive Menus

The HDMV Interactive Graphics framework is used to provide interactive Menu displays. For instance, changing the display image of selected Buttons and changing the graphics display of the page (Buttons appearing and disappearing) with Button activation. This framework enables the Content Provider to provide flexible Menu navigation while the movie is presented.

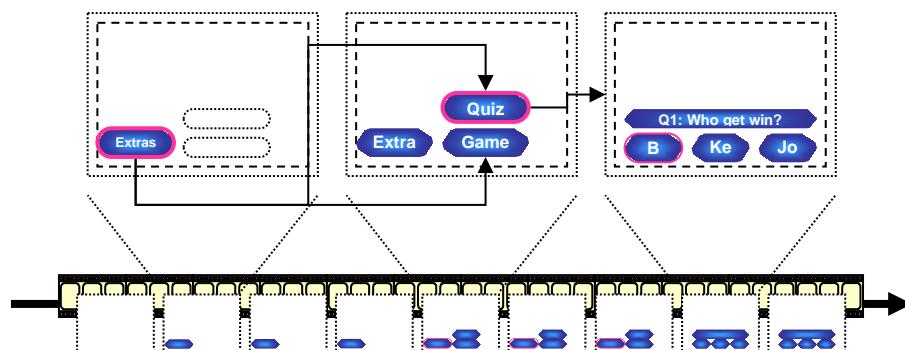


Figure 2-15 – Example of Multi-page Menu with dynamic Button display

2.2.2.2 Slideshow

2.2.2.2.1 Timebased Slideshow

The HDMV Timebased Slideshow is an application to present still pictures. It is same as movie presentation except that a presenting picture is a still picture. A still picture is coded as an MPEG-4 AVC IDR I-frame or an HEVC IDR I-frame. Presentation timing of the still picture is controlled by the associated PTS value and the presentation progresses with predefined timing axis. The stream of the Timebased Slideshow may contain data of Audio, Subtitle and Graphics. The presentation timing of these data is controlled by each PTS value in the stream.

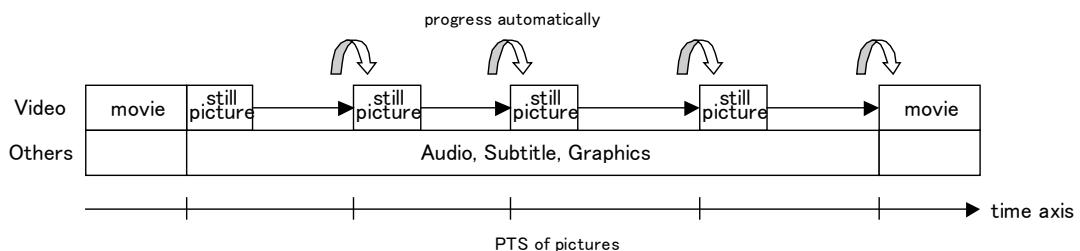


Figure 2-16 – Presentation Image of Timebased Slideshow

2.2.2.2.2 Browsable Slideshow

This format does not provide support for Browsable Slideshow.

2.2.2.2.3 Button sounds

Button Sounds is available in HDMV. Both the Select and Activate actions may be associated with short duration sounds which are mixed with the underlying audio.

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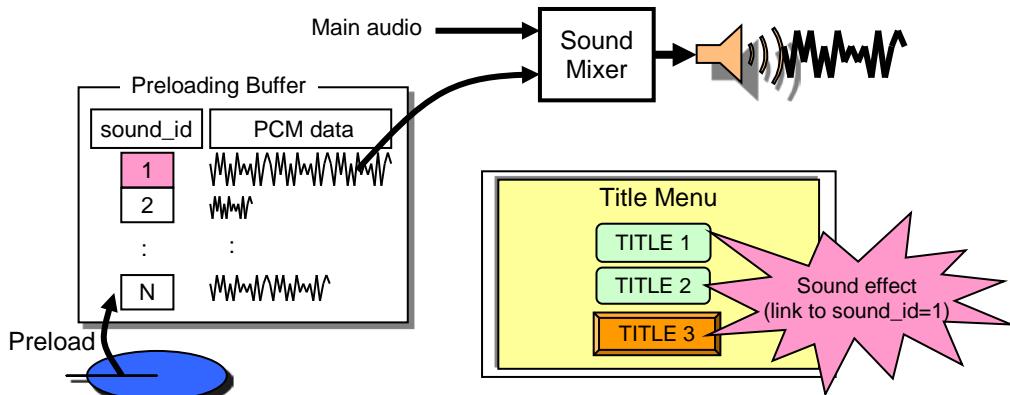


Figure 2-19 – Example of Button sounds

2.2.2.3 User Changeable Subtitle styles

This format does not provide support for user changeable Text Subtitle style.

2.2.2.4 Audio-only BD-ROM Players

This format does not provide support for Audio-only BD-ROM Players.

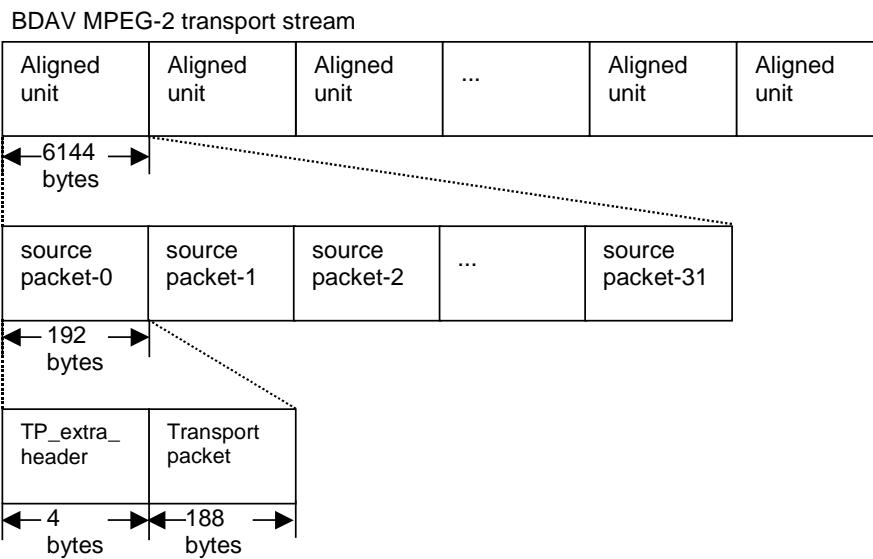
2.2.3 MPEG2 Transport stream for BD-ROM

The Blu-ray Disc Read-Only Format(BD-ROM) uses a common format for stream multiplexing – this format is based on the MPEG-2 Transport Stream industry standard (ISO/IEC 13818-1).

2.2.3.1 BDAV MPEG-2 Transport Stream

A MPEG-2 Transport Stream is stored in a Clip AV stream file in a structure known as the “*BDAV MPEG-2 Transport Stream*”. A BDAV MPEG-2 Transport Stream conforms to the data structure illustrated in Figure 2-21. The BDAV MPEG-2 Transport Stream is constructed from one or more “Aligned units”, where:

- 1) The size of an Aligned unit is 6144 bytes (2048*3 bytes).
- 2) An Aligned unit starts from the first byte of the source packets.
- 3) The length of a source packet is 192 bytes. One source packet consists of one TP_extra_header structure and one MPEG2 transport packet structure. The length of the TP_extra_header structure is 4 bytes and the length of the transport packet structure is 188 bytes.
- 4) One Aligned unit consists of 32 source packets.

**Figure 2-21 – Data structure of BDAV MPEG-2 transport stream**

Aligned units are recorded in three consecutive logical sectors on the BD-ROM disc. The size of one logical sector is 2048 bytes. The maximum multiplex rate of the MPEG-2 Transport Stream carried in the BDAV MPEG-2 transport stream data format depends on disc type and zone.

Table 2-1 – Maximum MPEG-2 transport stream bitrate

disc capacity	Maximum MPEG-2 transport stream bitrate
50GB	64 Mbps
50GB	81.7 Mbps
66GB	81.7 Mbps
66GB	109 Mbps
66GB (two zoned disc)	109 Mbps in LTR zone and 127.9 Mbps in HTR zone
100GB	81.7 Mbps
100GB	109 Mbps
100GB (two zoned disc)	109 Mbps in LTR zone and 127.9 Mbps in HTR zone

LTR zone is inner area and HTR zone is outer area of a two zoned disc. This format allows to use three different disc capacities (50/66/100GB) and two (for 50GB) or three (for 66/100GB) maximum bitrate options. The highest bitrate of MPEG-2 transport stream is 127.9Mbps for HTR zone of 66/100GB discs so that BD-ROM can provide the highest audio visual quality to the users.

The HTR zone spreads over approx. 92% of the disc capacity using all layers of the disc. Content author can utilize the entire volume of the HTR zone for seamless playback of the movie content applying the file allocation rules defined in the format.

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2.2.3.2 Elementary streams in BDAV MPEG-2 Transport Stream

Video, audio and graphics elementary streams are coded in the PES packet payload of the BDAV MPEG-2 Transport Stream. The coding method for each of these elementary streams is specified in Table 2-2 below.

A BDAV MPEG-2 Transport Stream is permitted to contain two Primary video streams for either HDR playback or SDR playback. Such BDAV MPEG-2 Transport Stream is called as a Dual Stream. In the Dual Stream, Primary audio streams are commonly used but Graphics streams are prepared individually for both HDR and SDR playback. HDR version of a Graphics stream and SDR version of the associated Graphics stream are identical except for CLUT values. See 2.2.3.5.

Table 2-2 – Elementary streams in the BDAV MPEG2 Transport Stream

Name of elementary stream	Coding method of elementary stream
Primary video stream	MPEG-4 AVC video stream
	HEVC video stream
Primary audio stream	Linear PCM audio stream
	Dolby Digital audio stream
	Dolby Digital Plus audio stream
	Dolby Lossless audio stream
	DTS digital surround audio stream
	DTS-HD audio stream
	DRA audio stream
	DRA Extension audio stream
	Presentation graphics stream
Graphics stream	Interactive graphics stream

2.2.3.3 Video streams

2.2.3.3.1 Primary video stream

Primary video stream is MPEG-4 AVC video stream or HEVC video stream.

The video formats shown in Table 2-3 can be used for Primary video streams. Not all BD-ROM Players support 25/50Hz video formats.

Table 2-3 – Specification of BD-ROM Primary video streams

Primary Video	Codec	HEVC (Main 10, High Tier, Level 5.1)	MPEG-4 AVC (High/Main Profile, Level 4.1/4.0)
	Max. bitrate	100 Mbps	40 Mbps
	Resolution	1920x1080, 3840x2160	1920x1080
	Frame rate	23.976p, 24p, 25p, 50p, 59.94p, 60p	23.976p, 24p
	Aspect ratio	16:9	16:9

2.2.3.3.2 HEVC (High Efficiency Video Coding)

This format utilizes HEVC (High Efficiency Video Coding) which is also referred to as H.265, as the successor to the MPEG-4 AVC used in the previous BD-ROM format. The HEVC standard is superior in that it allows almost a doubling of the video compression efficiency compared to the MPEG 4 AVC, effectively allowing 40% to 50% more video to be stored on a disc with the same capacity.

2.2.3.3.3 BT.2020 color space

In the current digital television eco-system, the color space is referred to as BT.709 and is capable of rendering approximately 35% of the visible color range for the viewer to discern (CIE color spectrum). BT.2020 significantly increases the visible capability to 75.8% of the CIE color spectrum.

This format defines a bit depth of 10 bits per sample, and includes UHD resolution in a 16:9 aspect ratio, together with support for BT.2020. An important advantage of higher bit depth in this new color space is that it allows a greater number of colors to be displayed.

BD-ROM players provide additional features to address playback to legacy displays, including BT.2020 to BT.709 color conversion and 3840x2160 to HD resolution down-scaling.

2.2.3.3.4 HDR (High Dynamic Range)

One of important features of this format is HDR video that brings a significant level of user experience enhancement. Video dynamic range is defined as the difference between the brightest whites and the darkest blacks in the image. This feature incorporates both a new kind of signal and new way to deliver that signal to next generation televisions. Similar to how color space functions, the human vision system is extremely adaptable to a large range of brightness. When looking at a typical outdoor scene with bright sun, the human eye can detect details in shadows as well as bright objects in the scene. The eye also can see and discern reflections of the sun off of windows or water, and can even look toward, but not at the sun itself. Figure 2-22 shows an example photograph of such a scene.



Figure 2-22 – A scene with very wide contrast between shadows and bright sun

Current video displays and televisions use SDR (Standard Dynamic Range) video. In this system the white objects are displayed but the reflections and the sun are displayed at very similar brightness levels. The video signal contains all the black and gray levels up to a pre-defined white point which typically consumes 95% of the available signal. These SDR video systems then compress all the remaining spectral information that the scene must contain into the remaining portion of the signal which is commonly about 5% or less of available digital signal. As a result, the displayed image on the televisions shows the white of the snow and the brightness of the sun and its reflections at essentially the same brightness level.

In the HDR imaging systems, only the lower 50% of the signal would be used to cover from black to white. This leaves the upper 50% to be used for reflections, explosions, bright lights or bright sun, etc. This upper portion also allows full color range to be included in brighter highlights, something not possible in current SDR television systems. Figure 2-23 is an illustration of the impact that HDR image can present to the consumer.

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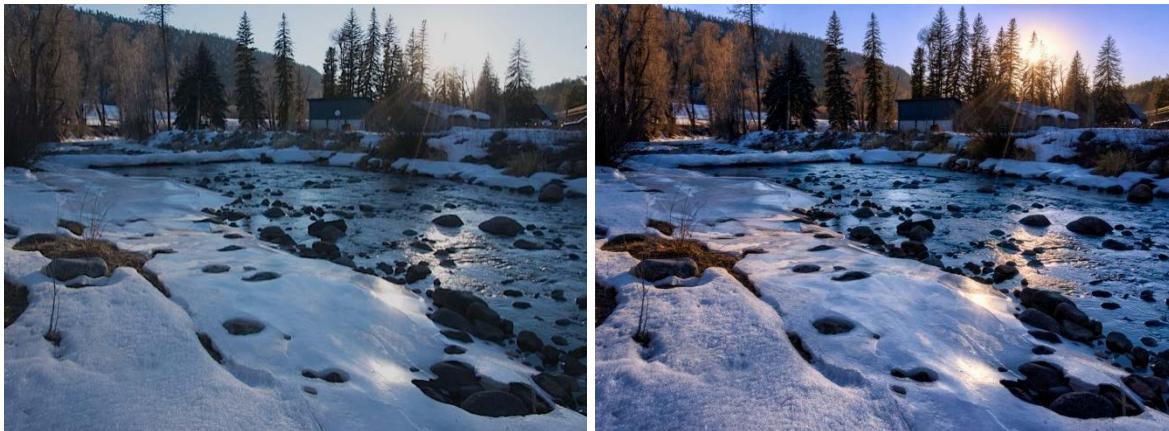


Figure 2-23 – SDR vs HDR impression comparison

SDR images (left) compress highlights to be the same value as normal white and therefore lose contrast and color information in the sky and on the trees. HDR images (right) display wide differences between white areas of the snow, reflections of the sun on the snow, and the sun itself with much higher contrast. Note that the blue color of the sky is restored to the image and the color detail throughout the image is enhanced.

2.2.3.3.5 Supported HDR technologies

This format defines three types of HDR video formats: BDMV HDR, Dolby Vision and Philips HDR. The BDMV HDR is the HDR video format which is mandatory for player in this specification. The Dolby Vision and Philips HDR are the optional HDR video technologies for players and discs. The Dolby Vision and Philips HDR technologies use metadata that has also been submitted to the SMPTE for consideration.

2.2.3.3.5.1 BDMV HDR

The BDMV HDR format is characterized by the following properties:

- BDMV HDR video stream is an HEVC video stream (10bit, YCbCr 4:2:0).
- color primaries: BT.2020 with non-constant luminance
- EOTF(Electro-Optical Transfer Function): SMPTE 2084
- Metadata: SMPTE 2086(Mastering display color volume) metadata, Maximum Content Light Level (MaxCLL), and Maximum Frame-Average Light Level (MaxFALL)

MaxCLL and MaxFALL are metadata that apply to HDR content only. MaxCLL indicates the maximum light level of pixel, in units of 1 cd/m^2 , in entire playback sequence of the BDMV HDR video streams in the PlayList. HDR content for Ultra HD Blu-ray will be created while considering the authoring guideline that over 1000 cd/m^2 should be limited to specular highlights which are expected to be a small percentage of the picture area (for the first two years from the start of this format license). Note, since the value of MaxCLL is computed with a max() mathematical operator, it is possible that the true CIE Y Luminance value is less than the MaxCLL value. This situation may occur when there are very bright blue saturated pixels in the stream, which may dominate the max(R,G,B) calculation, but since the blue channel is an approximately 10% contributor to the true CIE Y Luminance, the true CIE Y Luminance value of the example blue pixel would be only approximately 10% of the MaxCLL value.

MaxFALL indicates the maximum value of the frame average light level, in units of 1 cd/m^2 , in entire playback sequence of the BDMV HDR video streams in the PlayList. HDR content for Ultra HD Blu-ray will be created while considering the authoring guideline that the MaxFALL should not exceed 400 cd/m^2 (for the first two years from the start of this format license).

Note, the frame-average computation used to compute the MaxFALL value is performed only on the active image area of the image data. If the video stream is a "letterbox" format (e.g. where a 2.40:1 aspect ratio is put inside a 16:9 image container with black bars on the top and bottom of the image), the black bar areas are not part of the active image area and therefore are not included in the frame-average computation. This allows the MaxFALL value to remain an upper bound on the maximum

frame-average light level even if image zooming or pan/scan is performed as a post-processing operation.

The above metadata (SMPTE 2086, MaxCLL and MaxFALL) is stored in a PlayList file in the same format as defined in CEA specifications. See CEA861.3 for more information about the format of this metadata and the calculation of MaxCLL and MaxFALL values. BDA also defines “BD-ROM Part3 Guidelines for Content Authors and Player Implementers” as a part of BD-ROM Part3 V3.1 and the book describes the guidelines for the above metadata values.

2.2.3.3.5.2 Dolby Vision

The Dolby Vision video stream is composed of a BDMV HDR video stream and a Dolby Vision enhancement layer video stream. The enhancement layer is an HEVC video stream with embedded Dolby Vision metadata. The Dolby Vision video signal is characterized by the followings:

- color primaries: BT.2020 with non-constant luminance
- EOTF(Electro-Optical Transfer Function): SMPTE 2084
- Bit depth: 12bit (combination of BDMV HDR video stream and Dolby Vision enhancement layer)
- Enhancement layer video stream: 1920x1080 resolution, same frame rate with the BDMV HDR video stream, 100Mbps or lower together with the BDMV HDR video stream

2.2.3.3.5.3 Philips HDR

The Philips HDR video stream is a BDMV HDR video stream with Philips HDR SEI messages. The Philips HDR SEI messages is a metadata to control down-conversion of the dynamic range of the BDMV HDR video stream to a dynamic range of the connected display.

2.2.3.3.6 HDR-to-SDR conversion technologies

BD-ROM Players implement the HDR-to-SDR conversion feature, which converts BDMV HDR content to a format expected by a connected SDR display. Each player is free to choose its own implementation dependent conversion method for BDMV HDR content. BD-ROM players may choose to implement additional optional HDR-to-SDR conversion technologies that are defined in the specification.

Defined HDR-to-SDR conversion technologies are as follows.

- Dolby Vision HDR-to-SDR conversion
- Philips HDR HDR-to-SDR conversion
- CRI (Colour Remapping Information) conversion (CRI Supplemental Enhancement Information is a part of HEVC specification and published in January 2015)

If BDMV HDR content authors want to avoid BD-ROM player's implementation dependent HDR-to-SDR conversion for a connected SDR display, they have the option to include a SDR version of the content in the same transport stream (Dual Stream), in a separate transport stream on the disc, or in a transport stream on another disc in the package.

2.2.3.4 Audio streams

2.2.3.4.1 Primary audio stream

The BD-ROM specification defines eight types of Primary audio stream formats with various configurations and settings, as shown in Table 2-4 below. Some formats, configurations and settings are optional for BD-ROM Players.

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Table 2-4 – Specification of BD-ROM Primary audio streams

Primary Audio	Codec	LPCM	Dolby Digital	Dolby Digital Plus	Dolby Lossless	DTS digital surround	DTS-HD	DRA	DRA Extension
	Max. bitrate	27.648 [Mbps]	640 [kbps]	4.736 [Mbps]	18.64 [Mbps]	1.524 [Mbps]	24.5 [Mbps]	1.5 [Mbps]	3.0 [Mbps]
	Max.ch	8(48kHz, 96kHz), 6(192kHz)	5.1	7.1	8(48kHz, 96kHz), 6(192kHz)	5.1	8(48kHz, 96kHz), 6(192kHz)	5.1	7.1
	bits/sample	16, 20, 24	16 – 24	16 – 24	16 - 24	16, 20, 24	16 - 24	16	16
	Sampling frequency	48kHz, 96kHz, 192kHz	48kHz	48kHz	48kHz, 96kHz, 192kHz	48kHz	48kHz, 96kHz, 192kHz	48kHz	48kHz, 96kHz

2.2.3.5 Presentation Graphics and Interactive Graphics streams

BD-ROM provides two types of graphics streams as shown in Table 2-6 below. The Presentation Graphics stream (available in HDMV and BD-J) is intended for Subtitles and Animated Graphics, and the Interactive Graphics (available only in HDMV) is intended for Menu Graphics.

Table 2-6 – Specification of BD-ROM Graphics streams

Graphics	Plane size	1920x1080	
	Color	8bit Index lookup table (indicating YCbCr(8bit*3) + alpha(8bit))	
	Compression	Run Length Encoding	
	Presentation planes	2 planes	
	Presentation Plane name	Presentation Graphics	Interactive Graphics
	Main usage	Subtitles	Menus
	Animation Effects	Fade In/Out, Color changing, Wipe In/Out, Scrolling	

CLUTs of Presentation Graphics streams and Interactive Graphics streams are prepared by content author according to dynamic range property of the Primary video stream. If a Primary video stream is HDR, the Graphics streams have CLUTs expressed in BT.2020 color space primaries and ST2084 EOTF. If a Primary video stream is SDR, the Graphics streams have CLUTs expressed in BT.709 color space primaries and BT.1886 EOTF. The 8 bit YCbCr color values are quadrupled when 10 bit depth color space is used for graphics overlay process.

2.2.3.6 Text subtitle streams

This format does not provide support for user changeable Text Subtitle style.

2.3 Application Concepts of BD-J interactivity

This Section will cover the main features of the BD-J mode platform which is shown in Figure 2-24 below.

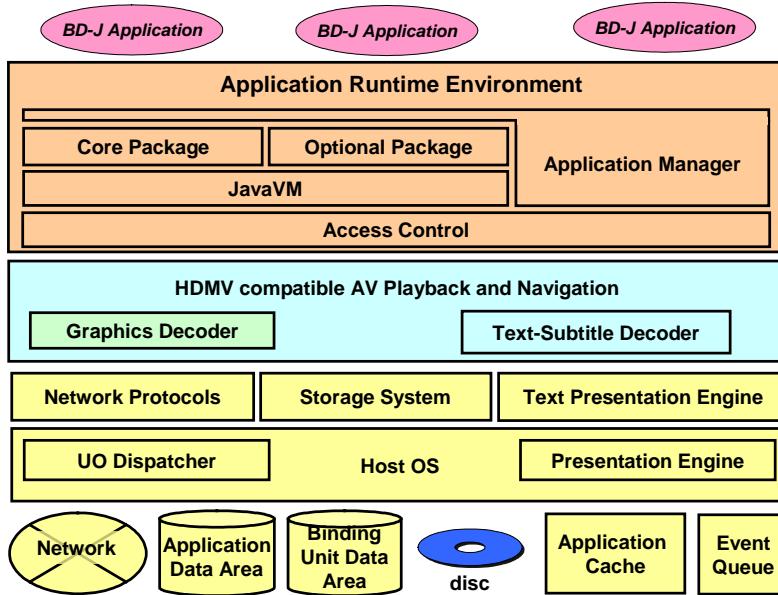


Figure 2-24 – Overall BD-J system model

BD-J is based on the Java 2 Micro-Edition (J2ME) Personal Basis Profile (PBP) – a Java profile that was developed for consumer electronics devices.

2.3.1 Core functions

2.3.1.1 Application Execution / Management

A key concept of BD-J is the BD-J Application. A BD-J Application is a Java Xlet that is registered in the Application Management Table (AMT). Each BD-J Title on a disc has an associated AMT which is stored in the title's BD-J Object.

At least one application in the AMT must be signaled as “autostart”. This application will be started when the corresponding Title is selected and from thereon the BD-J platform is used by the BD-J application. This could include selecting another Title and launching other applications signaled in the AMT or downloading from the Internet.

2.3.1.2 GUI framework and User Interface

BD-J includes a GUI framework that is suitable for a CE environment. A BD-J application's GUI can be operated with a remote control with a required set of keys and an optional pointing device. The set of required keys includes at least the keys needed to support the User Operations in HDMV applications.

The GUI framework in BD-J is similar to the framework defined in HAVi UI and is not a desktop GUI framework like Swing or AWT. The GUI framework will be based on the core of AWT, but the widget set includes mechanisms for remote control navigation and easy customization of look and feel.

2.3.1.3 Device model & functions like HAVi

BD-J includes a HAVi-like device model that maps to the BD-ROM system resources. One of the devices supported in the model is the Screen device that is build up of a Background Device, a Video

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Device and a Graphics Device. The configuration of the Screen and its constituent devices is under control of the BD-J application, as shown in Figure 2-25 below.

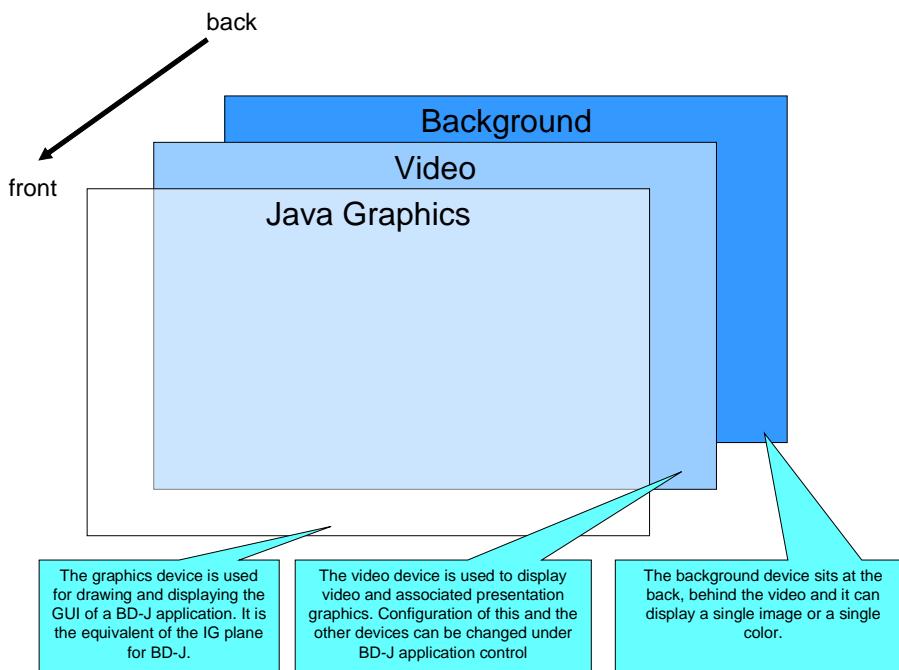


Figure 2-25 – BD-J system device model

The resolution of the Java graphics and Background plane is 1920x1080.

- When video plane is set to BT.709 color space, BD-ROM player matches the resolution, color space and bit-depth of the Graphics devices with the video device in overlay process.
- When video plane is set to BT.2020 color space, BD-ROM player matches the resolution and bit-depth. However the BD-ROM player does not support color space conversion nor dynamic range conversion of Java graphics and Background plane when mixing with video plane.

In the case where graphics assets are composed with BT.2020 HDR video, graphics assets shall be designed to be composed without player's SDR to HDR conversion. (e.g. preparing source graphics in BT.2020 color space for SMPTE ST2084 EOTF and storing that image data in PNG/JPEG graphics file format to create BD-J graphics asset.)

In the case where graphics assets are composed with BT.2020 SDR video, graphics assets shall be designed to be composed without player's color space conversion to the BT.2020 color space.

NOTE: All Ultra HD Blu-ray players have a capability to composite Java graphics and Background plane as above, however, there are some players that require a firmware update to support this mechanism.

BD-J graphics can use alpha for overlay with video. Additionally, the video can be scaled behind the BD-J graphics and the video background device can display a single image.

2.3.1.4 AV Playback and Navigation and Subtitle/Audio Language Control

BD-J includes a media framework similar to JMF for the playback of media content related to the BD-ROM disc. It is assumed that the BD-ROM disc will be the prime source for media files, but it will not be the only one; other sources could be the studio's web server and local storage.

The unit of playback in BD-J is the PlayList, just as in HDMV. All features of HDMV, except Interactive Graphics, can be used by a BD-J Application. HDMV Interactive Graphics is replaced by BD-J

graphics. Supported features include video, audio, Presentation Graphics component selection, media-time and playback-rate (trick-mode) control.

The BD-J Video Device is a combination of the HDMV Video and Presentation Graphics planes. Both Video and Presentation Graphics will play back in the Video Device.

2.3.1.5 Other (static) content format functions (Graphics, Text, Audio Clips)

BD-J includes standard Java libraries for decoding and displaying images in JFIF (JPEG), PNG and other image formats. These images can be displayed on the Java graphics plane using standard Java graphics functions. An image can also be rendered in the background plane using a BD-J specific package.

Text can be rendered using standard Java text functions. These text-rendering functions are extended with a more advanced text layout manager that integrates with the BD-J UI framework. The text is rendered using a vector-based font either coming from the disc, the BD-ROM Player (default font) or downloaded from the network.

Button sounds from HDMV can also be used by the Java UI framework. Sound files can be loaded and rendered as a reaction to the user pressing a key, or as a reaction on a marked event related to the movie - or as a reaction to any event generated by a BD-J Application.

2.3.1.6 Access control, security scheme, application authentication scheme

The BD-J environment uses the Java 2 security model to authenticate signed applications and to grant them permissions that go beyond the core functions (the BD-J defined sandbox).

The authentication scheme of BD-J applications is based on signing the JAR files that contain the applications. The relation between the authentication of BD-J applications coming from the disc and the Copy Protection System is out of scope for the Part 3, but an efficient workable scenario will be part of the BD-ROM specification. The BD-J classloader will only load authenticated applications when the disc is in the BD-ROM Player.

Authenticated applications can use a (signed) permission request file to acquire permissions that go beyond the BD-J sandbox. Permissions can be acquired for:

- Reading and writing to Local Storage of which there are two types - Binding Unit Data Area and Application Data Area
- Using the network connection (to connect to defined servers)
- Access of the file system on the BD-ROM disc
- Title selection of other titles on the BD-ROM disc
- Control of other running BD-J applications

2.3.1.7 Internet Connectivity & Download of New Contents/Applications

BD-J contains the Java network package. Java applications can use this package to connect to servers on the Internet. The physical connection might differ between implementations e.g. Ethernet, telephone line, etc. At the network level, TCP/IP is supported and the HTTP protocol may be used. Moreover, the Java package for secure connections is included (JSSE) as part of the BD-J platform. Before a BD-J application can use the network connection, it must be authenticated and have suitable permission to use the network.

The web sites to which the application will go are under full control of the Content Provider. This control is guaranteed in two ways:

- Only (disc) authenticated BD-J applications are allowed to run when the disc is played. The application controls the use of the network connection.
- In addition, permissions defined on the disc can restrict the use of the (TCP/IP) network connection to certain sites.

2.3.1.8 Application Data Area and Binding Unit Data Area

BD-J will include support for Local Storage. Two flavors of Local Storage are included – mandatory Application Data Area and optional Binding Unit Data Area. All Local Storage is accessed using methods from the Java IO package.

Application Data Area is Local Storage that will be present in all BD-ROM Players for BD-J mode. The required minimum size of this Application Data Area will permit storage of application data like settings, high-scores etc. It will not be big enough to store downloaded AV material. For this purpose, optional Binding Unit Data Area is available. Typically the Application Data Area will be implemented using Flash memory and the optional Binding Unit Data Area will be implemented on a HDD and/or a user expandable storage / user removable Local Storage.

Since storage is a shared resource between all discs played on the BD-ROM Player, Java access control is part of BD-J. BD-J applications can only access a disc specific part of the storage space and cannot access the part belonging to other discs.

2.3.1.9 Binding scheme for on-the-disc and off-the-disc content

A binding scheme between media content (AV files, subtitles, Java applications files, database files) on the disc and content (related to the disc) stored in the Binding Unit Data Area is defined. This scheme enables a seamless user experience to be provided when playing back media data, regardless of the origin of the data.

2.3.2 Application Examples

BD-J allows many possible application types. In this Section we will cover a few typical examples in more detail.

2.3.2.1 AV playback control

One of the main features of BD-J is playback of A/V material. A disc bound BD-J application can be created which is started when the disc is put into the BD-ROM Player. This application could present a Menu on the screen, e.g. while playing an introduction of the movie in a scaled-down manner in a corner of the screen which allows language selection, chapter selection, and display of background information that might be retrieved from disc or from the Internet. Once the user selects playback of a Title, the disc application becomes invisible but allows the user to use trick modes with a simple on-screen GUI on top of the video (as long as the application on the disc allows this). The user also has the option of going back to the full-screen Menu of the disc application using one of the remote control keys.

BD-J features used in this example include: media control (including video scaling, playback speed, language component selection), GUI framework, and Internet connectivity.

2.3.2.2 Subtitle Updates

The BD-J application described above can be further extended to allow the user to obtain subtitles in a language that is not supported on the disc. The Content Provider can publish new or updated subtitle files on a website dedicated to the disc Title. The BD-J application on the disc can include the retrieval of this subtitle file and storage from the website. After storing the subtitle file in the Binding Unit Data Area and creating a new Virtual Package containing the new subtitle streams, the application can select the new subtitles for a Title.

Only BD-ROM Players and trusted and authenticated applications will be able to do this and only from trusted and authenticated websites. The trust scheme will make use of the Java 2 security scheme and be tied to the CPS of the disc.

Additional BD-J features used in this example: downloading data into the Binding Unit Data Area, combined playback of subtitles from the Binding Unit Data Area with video from disc, merged file-system view, Java 2 security model.

2.3.2.3 Download new Movie trailer

When the Content Provider that published the disc is launching a sequel to the Title, they may also choose to publish a trailer for the sequel on their website, specifically for holders of the current title. A BD-J application, present on the disc, can connect to this website and see if there is new content available. The BD-J application can inform the user that a trailer for the new sequel movie is available e.g. by showing a number of (JPEG) images in the Main Menu. After the user has selected to view the trailer, the BD-J application downloads this trailer, while at the same time showing some background information on the actors in this sequel. When the download of the trailer to the Binding Unit Data Area is completed, the application creates a new Virtual Package and plays it back, showing at the bottom of the screen the movie theatres where this movie can be seen.

Additional BD-J features used in this example: downloading A/V material to the Binding Unit Data Area, playback of A/V material from the Binding Unit Data Area using Virtual Package, display of (JPEG) images from Local Storage (Binding Unit Data Area or Application Data Area), retrieval and usage of user information (for the display of localized information).

2.3.2.4 Play games on the disc and also online game

BD-J is not only a good solution for flexible media-playback from disc and from the Internet, it can also be used for games. A disc can contain, besides the movie Title, a Title that contains a set of games. The Java application associated with the Title displays the Menu of available games. The set of games can be a combination of games coming from the disc and games downloaded in JAR files from the Content Provider's website. Games can retrieve high scores from the Internet and achieving a new high-score can result in the user's alias appearing in the updated game results. Game applications can make use of the Java graphics and UI input features of the Java programming environment.

Additional BD-J features used in this example: multiple application support, Java graphics, user input (keys, optional pointing device).

2.3.2.5 Advanced Applications

With the features described above it is possible to create advanced applications, for example:

- An online shopping application that may allow the end-user to buy Title related merchandising.
- Chat applications that may allow on-line discussion with other purchasers of the same Title.

2.3.2.6 Application Illustrations

Figure 2-26 below, further illustrates potential BD-J application types. This illustration includes an application that allows a movie director to give comments on the movie, to control playback of the disc and to point to certain items in the video. Note that this does not have to be a live commentary, but can be scripted at the server side.

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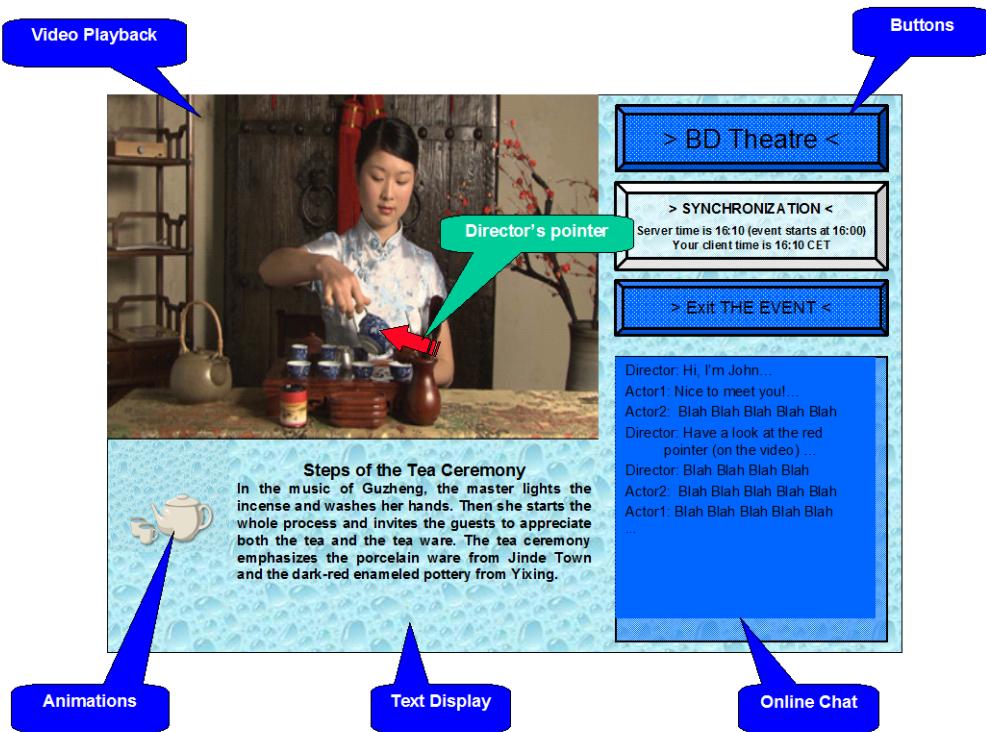


Figure 2-26 – Example of BD-J application

The four pictures below illustrate the use of multiple concurrent applications. One typical example of this is a main application that controls media playback and a second application that displays some information transparently on top of the video. The main game Menu that allows launching various games is another example.

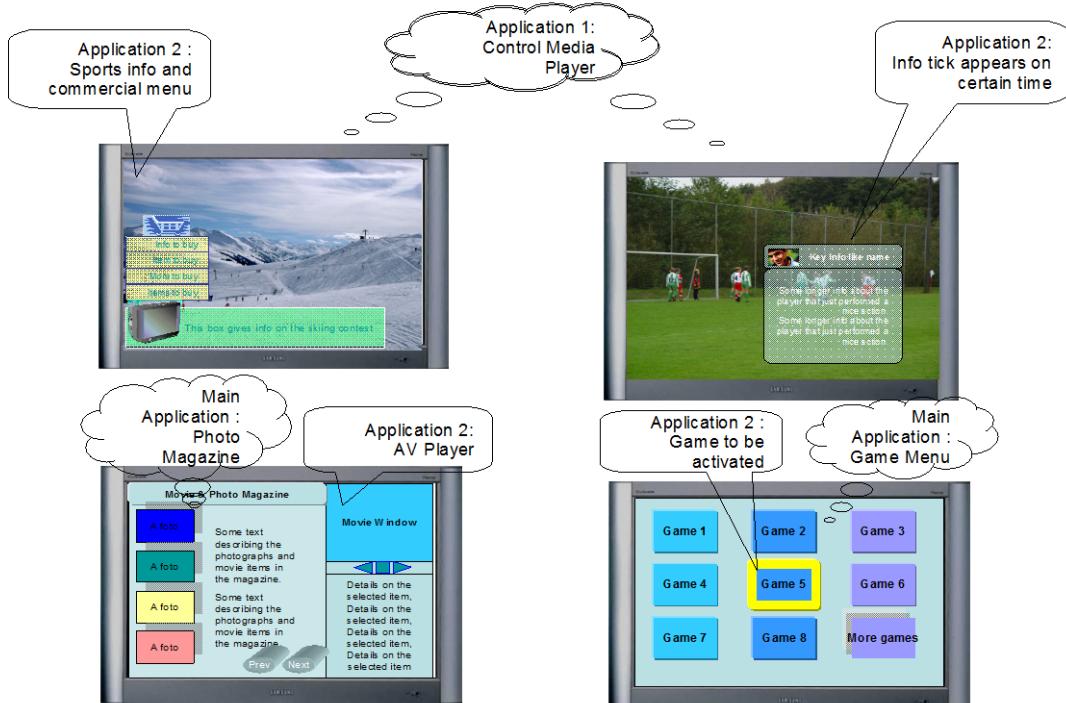


Figure 2-27 – Example of multiple concurrent BD-J applications

2.4 Application Concepts of Metadata

2.4.1 Application Example of Disc Library

This Section describes application concepts for utilizing the metadata. Metadata is defined to be the “data about a data.” By using standardized metadata, the content can be described in a consistent format, and such metadata can be used to search a disc or a multimedia title with certain features.

2.4.1.1 Disc Search

A standardized metadata of the content on a disc may form a collection when metadata of more than one disc are gathered. This metadata collection may function as a type of a disc library that has information about the contents in multiple discs. With this descriptive information about the content, a Disc Library may enable a BD-ROM Player to search and identify a disc and/or a title. The illustration of the application is shown in Figure 2-28.

As shown in Figure 2-28, metadata of a disc is stored in a separate file. It should consist of a Disc Information and more than one Title Information of a disc. The thumbnail images that are related to the content can be stored with the metadata file of a disc. A Disc Information is metadata about a disc itself, and a Title Information is metadata about a content title in the disc. Hence, only one Disc Information and more than one Title Information shall be included in the metadata file of a disc. The thumbnail image representing a disc shall be included to be referenced by the Disc Information metadata. The thumbnail images may exist per each title in a disc. The metadata file of a disc is copied into the local storage of the BD-ROM Player when the disc is inserted. When the metadata of inserted discs are accumulated, a Disc Library is formed in the BD-ROM Player.

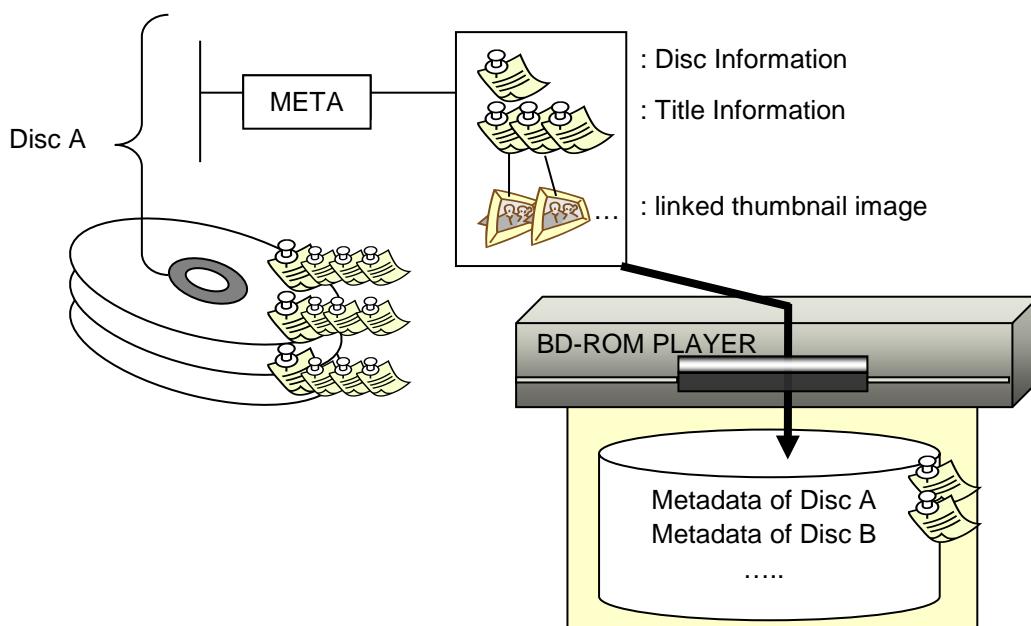


Figure 2-28 – Illustration of Disc Library

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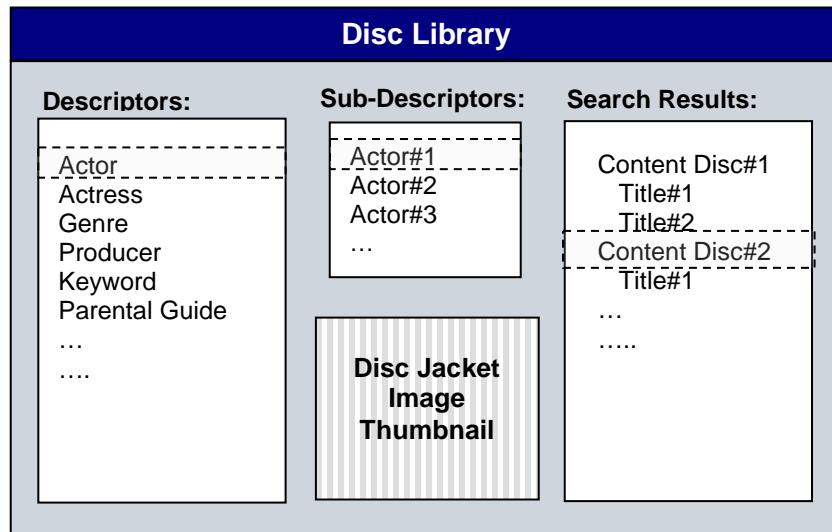


Figure 2-29 – Exemplary Application UI of Disc Library

When the user selects a certain result from the list, more detailed information of selected disc or title should be displayed as shown in Figure 2-30. The Disc Information or the Title Information of a selected result may be displayed in a form described in the figure. Metadata of the selected content may be displayed with a corresponding thumbnail image.

In showing the Disc Information of a selected result, some metadata from a representative Title Information would be presented to help user's comprehension on the content. For instance credits or promotional information are rather the information about the content in the title, than information about a disc itself. However, by showing such information with other Disc Information, the user can easily identify the disc and its features.

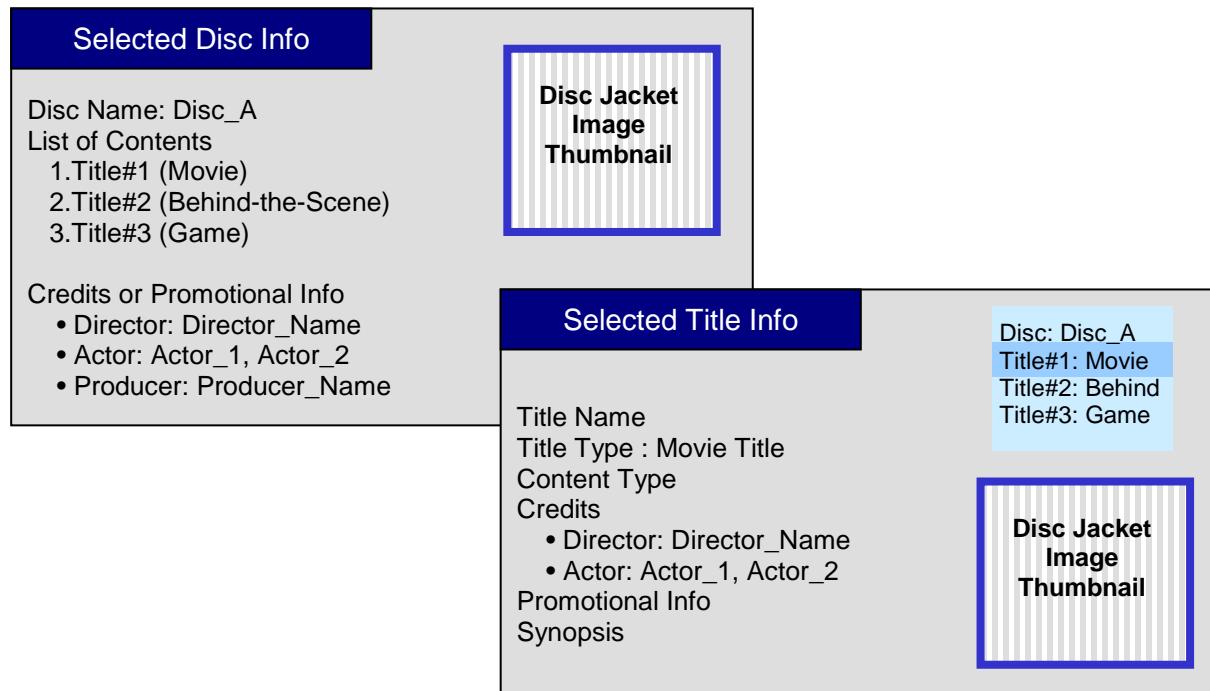


Figure 2-30 – Exemplary UI for Showing Details of Searched Results

2.4.2 Application Example of Title Scene Search

This Section explains the application examples of utilizing metadata for Title Scene Search. A Title Scene Search is an advanced version of chapter search where metadata on each scene of the content enables a specific scene search. Using a standardized metadata of Title Scene Search, every scene constituting the content can be described one by one and also can be searched using specific search keywords.

2.4.2.1 Search within the Content

A standardized metadata can be used to describe the content scene by scene. The content can be divided into multiple scenes, and metadata can be mapped per each scene describing the content using a predefined format of descriptors. Metadata with these scene descriptions can be used to search the content, and show the matching result to the user.

2.4.2.2 Search Triggered by Keywords

While the playback of a movie title, a user can search a specific scene with desired search keywords. As shown in Figure 2-31, a user selects a “Title Scene Search” function to generate the corresponding user interface (②) while playback. If a user selects the desired search keyword, a list is shown with the specific values of that keyword (③). According to the value the user selected, the content is searched and the results are listed in scenes with thumbnail pictures representing each scene (④). The user choose a scene from the list shown, and the movie should be presented from the point selected (⑤).Using the remote controller, a user can skip to the next or previous searched result (⑥) without going back to the menu that shows the list of searched results.

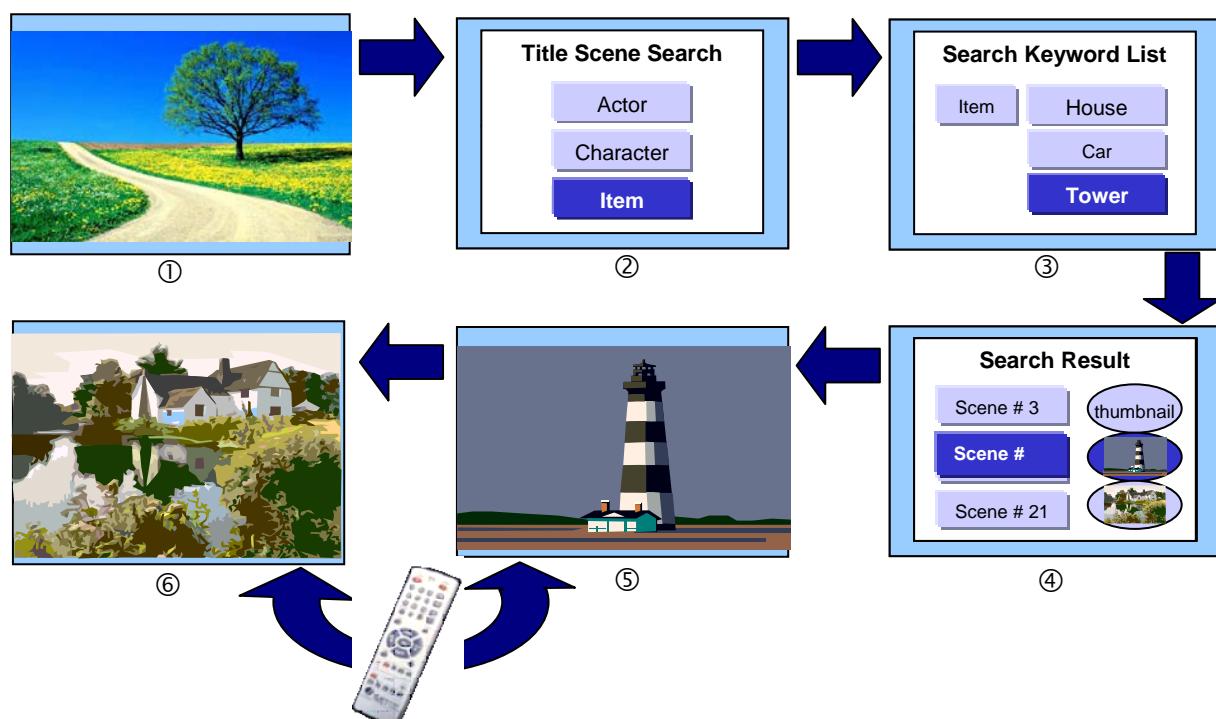


Figure 2-31 – Title Scene Search Triggered by Keywords

If there is no other user operation through remote controller, the playback of searched result should continue till the end of the content. However, if a user activate “Title Scene Search” function again while playback of searched result, the application may return to the menu which shows the searched results (④). The user can either terminate the function or choose new keyword for another scene search.

2.4.2.3 Search Triggered by Scene

Another application example of Title Scene Search is shown in Figure 2-32. Figures from ① through ⑥ describe the application example explained in 2.4.2.2. In addition to the application example, a user can press the “Title Scene Search” function to show the list of search keywords that are included in the content scene at the moment (⑦, ⑧). Among the search keywords of the scene, a user can choose a keyword that can be used in searching the content of corresponding match (⑧). Similar to Figure 2-31, the searched results are shown in the list for the user to choose one for playback (⑨). A user can also skip to the next or previous searched scene with an appropriate input through a remote controller without going back to the search-result menu.

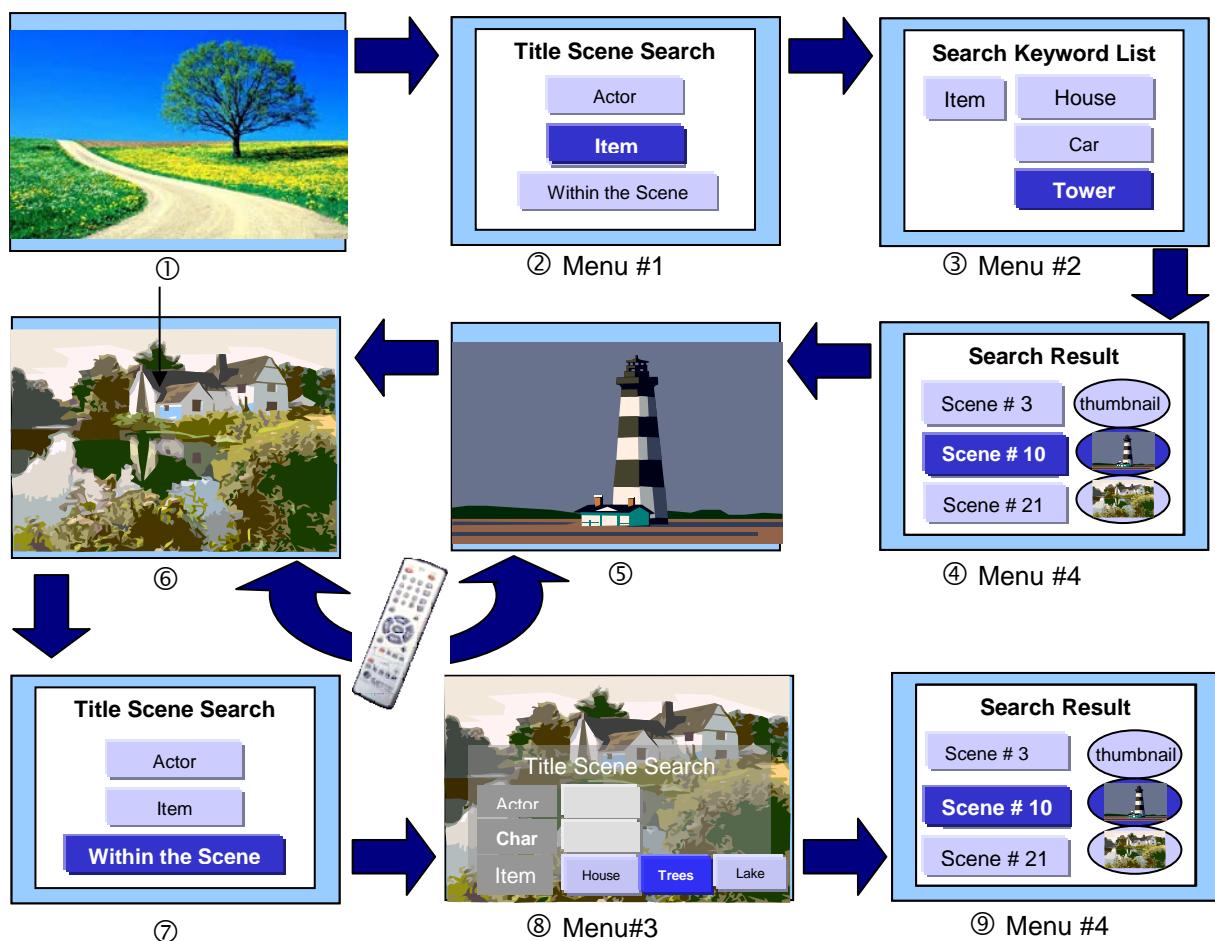


Figure 2-32 – Search Triggered by Scene

If there is no other user operation through the remote controller, the playback of searched result should continue till the end of the content. However, if a user activate “Title Scene Search” function again while playback of searched result, the application may return to the menu which shows the searched results (step④ in case of playback step⑤ or ⑥). The user can either terminate the function or choose new keyword for another scene search.

2.4.2.4 Search to See the Highlights

Instead of waiting for the user's selection to playback certain searched results, a successive playback of all the searched results may be possible. If a user selects a keyword to search within the content, related search results can be extracted and form a highlight consisted of continuous search results. In order to make such highlights, search results shall be expressed using entry points with associated optional duration for each. With entry point and optional duration information, results can be connected and played continuously (Figure 2-33).

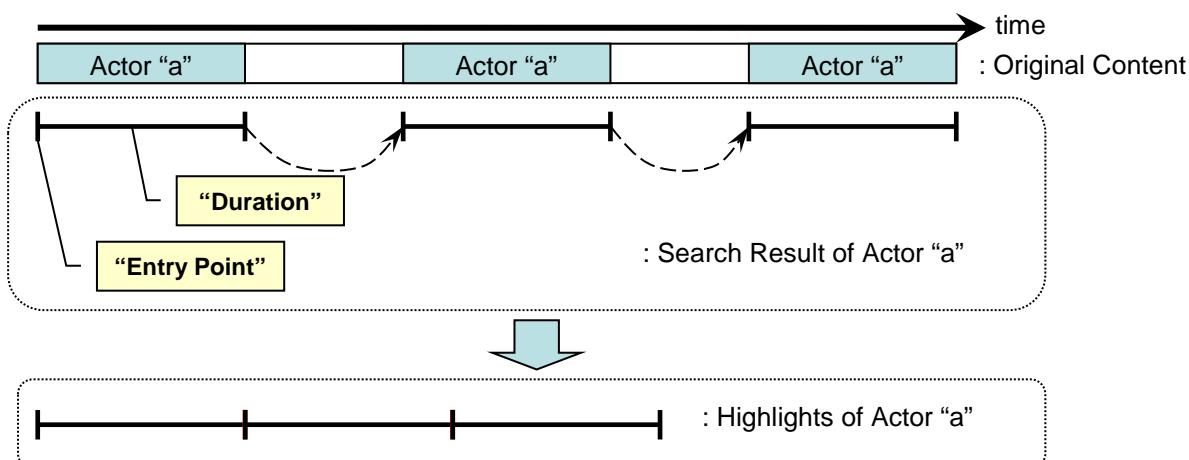


Figure 2-33 – Highlights Consisted of Search Results

In case of Figure 2-33, a user selects actor "a" as a keyword of the content search. Parts of the content related with actor "a" are searched and extracted with entry points and associated optional duration information. The searched results are connected to be played continuously in sequence. When the playback of search-result highlights is finished, the application may return to the menu where the user selected the search keyword of Title Scene Search. The user can either terminate the Title Scene Search function or choose other search keywords.

2.4.3 Application example of Track/Chapter display

This Section explains the application example of utilizing metadata for track/chapter name display. Using a standardized metadata of track/chapter name display, a track name or a chapter name can be informed to a user even in a restricted display device.

2.4.3.1 Application Example of Track/Chapter Metadata

Application of Part3 encompasses audio centric contents and it also allows products with constrained display devices such as car audio system. The metadata for track/chapter name provide information of the name of each audio track in text format, and the names can be presented on the constrained display devices. Figure 2-34 shows an example of such environment with display of content type (e.g. Audio), track number, and track name.



Figure 2-34 – Application Example of Track/Chapter Name Display on constrained device

It is defined that audio tracks compose a title, and each track corresponds to a chapter of a Movie Title. There are one to one correspondence between an audio track and a chapter in sequential order. With the definition, information of track number, playback time and track name can be presented.

2.5 Application Concepts of Stereoscopic 3D

This format does not provide support for Stereoscopic 3D.

3 HEVC coding constraints

This section is indented to provide the coding constraints on HEVC video streams as defined in the BD-ROM Part3 V3.1 specification. This information is intended to be used for the development of video encoders, not limited to BD-ROM Licensees to improve the interoperability.

HDMV HEVC video stream shall comply with the ITU-T Rec. H.265. Additional constraints on HEVC video stream are specified in this section.

3.1 General Constraints

- Profile
 - Main 10 profile
 - general_profile_idc in SPS shall be set to 2.
- Tier
 - High Tier
 - general_tier_flag in SPS shall be set to 1.
- Level
 - Level 5.1
 - general_level_idc in SPS shall be set to 153.
- The following conditions shall not change in a HDMV HEVC video stream carried within the transport packets with the same PID value in a Clip AV stream file.
 - pic_width_in_luma_samples
 - pic_height_in_luma_samples
 - aspect_ratio_idc
 - colour_primaries
 - transfer_characteristics
 - matrix_coeffs
 - Frame-rate = vui_time_scale / vui_num_units_in_tick
 - vui_time_scale^(Note)
 - vui_num_units_in_tick^(Note)
 - BitRate[cpb_cnt_minus1], which is derived from bit_rate_scale and bit_rate_value_minus1 in hrd_parameters().
 - CpbSize[cpb_cnt_minus1], which is derived from cpb_size_scale and cpb_size_value_minus1 in hrd_parameters()

(Note):

It is recommended to use combination of 'vui_num_units_in_tick' and 'vui_time_scale' in the table below.

Frame-rate [Hz]	vui_time_scale	vui_num_units_in_tick
23.976	24000	1001
24	24000	1000
25	25000	1000
50	50000	1000
59.94	60000	1001
60	60000	1000

- The following conditions should not change in a HDMV HEVC video stream carried within the transport packets with the same PID value in an AV stream file.
 - overscan_info_present_flag
 - overscan_appropriate_flag
- End of bitstream (end_of_bitstream_rbsp()) shall not occur in the HDMV HEVC video streams, except for the following case.

HEVC coding constraints

- At the end of the video access unit which contains an end_of_seq_rbsp().
- The following fields in SPS shall have the following pre-determined values.
 - general_profile_space shall be set to “0”.
 - sps_temporal_id_nesting_flag shall be set to “1”.
 - colour_description_present_flag shall be set to “1”.
 - chroma_format_idc shall be set to “1”.
 - vui_parameters_present_flag shall be set to “1” (VUI parameters shall be present).
 - aspect_ratio_info_present_flag in VUI parameters shall be set to “1”.
 - vui_hrd_parameters_present_flag in VUI parameters shall be set to “1”.
 - vui_timing_info_present_flag in VUI parameters shall be set to “1”.
 - nal_hrd_parameters_present_flag in VUI parameters shall be set to “1”.
 - sub_pic_hrd_params_present_flag in VUI parameters shall be set to “0”.
 - fixed_pic_rate_general_flag in HRD parameters shall be set to “1”.
 - overscan_appropriate_flag should be set to “0” if overscan_info_present_flag is set to 1.
 - bit_depth_luma_minus8 shall be set to “2”.
 - bit_depth_chroma_minus8 shall be set to “2”.
- The following fields in PPS shall have the following pre-determined values.
 - dependent_slice_segments_enabled_flag shall be set to “0”.
- Only progressive source is used and all pictures shall be encoded as a frame.
 - general_progressive_source_flag in SPS shall be set to “1”.
 - general_interlaced_source_flag in SPS shall be set to “0”.
 - general_frame_only_constraint_flag in SPS shall be set to “1”.
- The no_output_of_prior_pics_flag shall be set to “0”.
- The following fields in VPS shall have the following pre-determined values.
 - vps_temporal_id_nesting_flag shall be set to 1.
 - general_profile_space shall be set to 0.
 - general_profile_idc shall be set to 2.
 - general_tier_flag shall be set to 1.
 - general_level_idc shall be set to 153.
 - general_progressive_source_flag shall be set to “1”.
 - general_interlace_source_flag shall be set to “0”.
 - general_frame_only_constraint_flag shall be set to “1”.
 - fixed_pic_rate_general_flag in HRD parameters, if present, shall be set to “1”.

3.2 GOP Structures

HDMV HEVC defines a GOP (Group of Pictures) structure for random access point at a reasonable time interval in the BD-ROM specification. The GOP structure is defined by:

- Picture type and reference structure

HDMV HEVC defines picture type and the reference structure of each picture type.

 - Picture type is defined as follows.
 - I picture: A picture that consists only of I slices, in which slice_type is set to 2.
pic_type in Access unit delimiter is set to 0.
IDR picture and CRA picture is a type of I picture. Definition of an IDR picture and CRA picture follows ITU-T Rec. H.265.
 - P picture: A picture that consists only of P slices, in which slice_type is set to 1.
pic_type in Access unit delimiter is set to 1.
 - B picture: A picture that consists only of B slices, in which slice_type is set to 0.
pic_type in Access unit delimiter is set to 2.

Two type of B picture is defined as follows.

- ❖ Bb picture: A B picture, in which bi-directional prediction is allowed.
- ❖ Bu picture: A B picture, in which only uni-directional prediction is allowed.

(Note) The term “Bb picture” and “Bu picture” is defined for the specification explanation purpose only. Both pictures consists only of B slices, in which slice_type is set to 0, and pic_type is set to 2.

- In case consecutive non-reference B pictures precede their reference picture in display order, they shall appear immediately after the reference picture in decoding order.
- The decoding order and display order of reference pictures (I or P or Bu pictures) shall be the same.
- The decoding order and display order of non-reference B pictures shall be the same.

Figure 3-1 and Figure 3-2 show examples of reference structure of a reference Bb picture and a non-reference Bb picture.

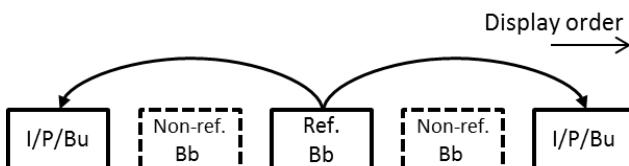


Figure 3-1 – Example of reference structure of a reference Bb picture

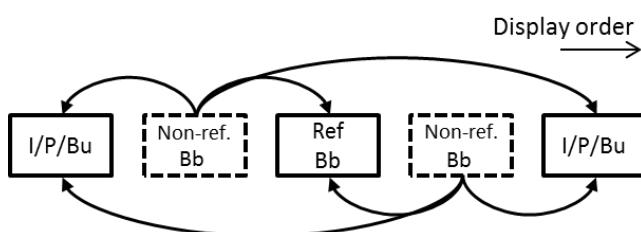


Figure 3-2 – Example of reference structure of a non-reference Bb picture

- Data structure
 - The first access unit is an IDR picture or a CRA picture in a GOP in decoding order.
 - One SPS (Sequence Parameter Set) shall be provided in the first access unit of every GOP. This SPS is referenced by all PPSs (Picture Parameter Set) in a GOP and no other SPS shall appear in a GOP, i.e. subsequent access units in a GOP shall have no SPS. An I picture which has a SPS indicates the start of a GOP (in decoding order).
 - One VPS (Video Parameter Set) shall be provided in the first access unit of every GOP.
 - A PPS shall be stored in the first access unit or in the access unit that refers to this PPS in a GOP with the following restrictions.
 - Maximum number of PPSs that can be stored in an access unit is defined as follows.
 - There shall be at least one and at most 30 PPSs in the first access unit in a GOP.
 - There shall be one or zero PPSs in each access unit, except for the first access unit in a GOP
 - Decoding delay that is indicated by sps_max_num_reorder_pics in SPS shall be equal to or less than 3 pictures (frames) period, i.e. the PTS of the first presented picture in a GOP minus the DTS of the first decoded picture in the GOP shall be less than or equal to 3 pictures period.

3.2.1 Open GOP and Closed GOP

GOP for HDMV HEVC video streams defined in the BD-ROM specification has “Open GOP” and “Closed GOP” that corresponds to GOP in ISO/IEC 13818-2 (MPEG-2 video). Closed GOP starts with an IDR picture and Open GOP starts with a CRA picture.

Closed GOP:

The first picture in decoding order is an IDR-picture. Because an IDR picture resets picture referencing over GOP boundary, all pictures in a closed-GOP can correctly be decoded even when random access to this GOP is executed.

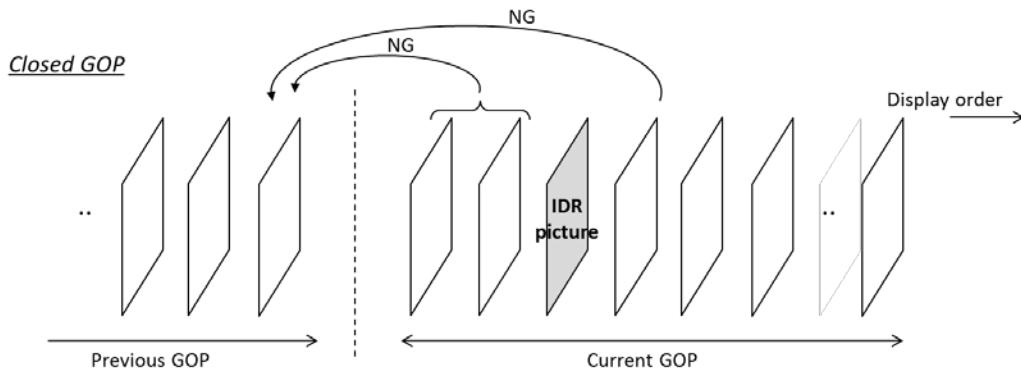


Figure 3-3 – Example of Closed GOP

Open GOP:

The first picture in decoding order is a CRA picture. Because a CRA picture does not reset picture referencing over GOP boundary, pictures prior to the CRA picture in display order cannot be correctly decoded when random access to this GOP is executed.

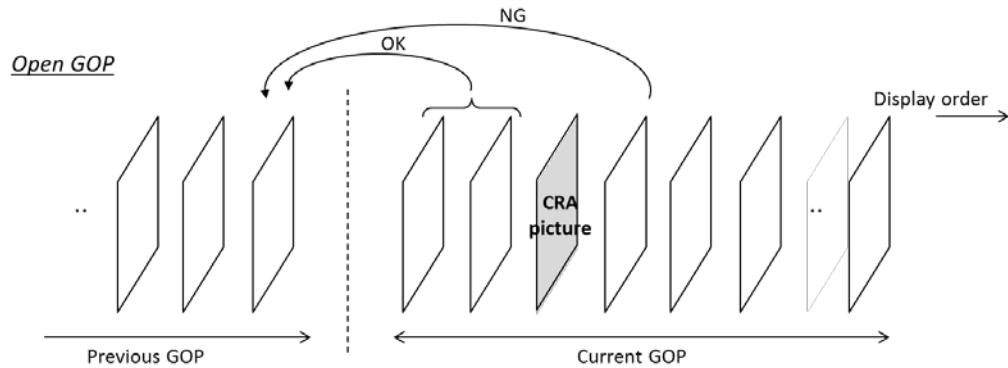


Figure 3-4 – Example of Open GOP

3.2.2 Other constraints on GOP

HDMV HEVC video streams shall conform to the following constraints.

- The number of video pictures displayed in a GOP of the HDMV HEVC video stream shall be less than or equal to the maximum number as defined in Table 3-1.

Table 3-1 – Maximum number of video pictures displayed in a GOP

Video format	Frame-rate [Hz]	general_frame_only_constraint_flag	Maximum number of frames displayed in a GOP
3840x2160 video format	23.976	1	24
	24	1	24
	25	1	25
	50	1	50
	59.94	1	60
	60	1	60
1920x1080 video format	23.976	1	24
	24	1	24
	25	1	25
	50	1	50
	59.94	1	60
	60	1	60

3.3 NAL units in Access Unit

An access unit (AU) in HDMV HEVC video streams shall be composed of multiple of segments, each of which is carried by following NAL (Network Abstraction Layer) units.

- First access unit (AU) in a GOP shall have following NAL units in listed order.
 - An Access unit delimiter NAL unit
 - A VPS NAL unit
 - A SPS NAL unit
 - PPS NAL unit(s)
 - Prefix SEI NAL unit(s) – if exist^{(Note1), (Note2), (Note3), (Note4)}
 - Slice segment(s) NAL units of an IDR or a CRA picture
 - Suffix SEI NAL unit(s) – if exist
 - A Filler data NAL unit – if exist^(Note5)
 - An End of sequence NAL unit – if exist
 - An End of bitstream NAL unit – if exist

- Subsequent access unit (AU) in a GOP shall have following NAL units in listed order.
 - An Access unit delimiter NAL unit
 - A PPS NAL unit – if exist
 - Prefix SEI NAL unit(s) – if exist^{(Note1), (Note2), (Note3), (Note4)}
 - Slice segment(s) NAL units of a picture
 - Suffix SEI NAL unit(s) – if exist
 - A Filler data NAL unit – if exist^(Note5)
 - An End of sequence NAL unit – if exist
 - An End of bitstream NAL unit – if exist

(Note1): Active parameter sets SEI message shall exist in the first AU in a GOP.

(Note2): Buffering period SEI message shall exist in the first AU in a GOP.

(Note3): Picture timing SEI message shall exist in every AU.

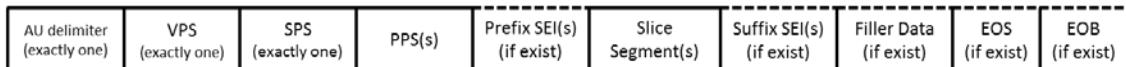
(Note4): User data unregistered SEI message and Mastering display colour volume SEI shall be stored in a Prefix SEI NAL unit, if exist.

(Note5): Filler data NAL unit can be placed in any position unless it precedes the first Slice segment NAL unit.

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HEVC coding constraints

First AU in GOP



Subsequent AUs in GOP

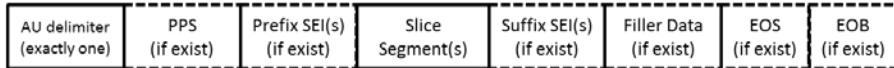


Figure 3-5 – NAL units in Access Unit

3.3.1 Use of temporal sub-layer

If HDMV HEVC video stream is coded with temporal scalability, fast playback can be done by decoding part of temporal sub-layers. Temporal scalability is realized by using TSA (Temporal Sub-layer Access) NAL unit. As defined in ITU-T Rec. H.265, a TSA picture and pictures following the TSA picture in decoding order do not use pictures prior to the TSA picture in decoding order with TemporalId greater than or equal to that of the TSA picture for inter prediction reference. A TSA picture enables up-switching, at the TSA picture, to the sub-layer containing the TSA picture or any higher sub-layer, from the immediately lower sub-layer. TSA pictures must have TemporalId greater than 0. Use of temporal sub-layer is optional. Following constraints are applied if temporal sub-layer is used.

- Maximum number of temporalID is 3, i.e.sps_max_sub_layers_minus1 is 3.
- TemporalID of I, P, Bu picture shall be set to 0.

3.4 Still picture

HDMV HEVC video streams uses “HEVC still picture” defined in “13818-1:2013/AMD 3” for still picture. In addition to the above definition HDMV HEVC video streams further restricts the following conditions.

- fixed_pic_rate_general_flag shall be set to 1 in the vui_parameters() of SPS that precedes an HEVC still pictures.
- An HEVC still picture shall contain End of sequence NAL unit to terminate HEVC video streams.
- An HEVC still picture shall be a frame with frame coding.
- An HEVC still picture is repeatedly displayed until the PTS of the next AU, if present.
- Minimum PTS interval of the two consecutive still pictures is 0.5 second.
- Access unit (AU) of an HEVC still picture shall have following NAL units in listed order^(Note).
 - An Access unit delimiter NAL unit
 - A VPS NAL unit
 - A SPS NAL unit
 - A PPS NAL unit
 - Prefix SEI NAL unit(s) – if exist
 - Slice segment(s) NAL units of an IDR picture
 - Suffix SEI NAL unit(s) – if exist
 - A Filler data NAL unit – if exist^(Note1)
 - An End of sequence NAL unit
 - An End of bitstream NAL unit – if exist

(Note): Filler data NAL unit can be placed in any position unless it precedes the first slice NAL unit.

3.4.1 Frame-rate of still pictures

End of sequence NAL unit terminates the HEVC sequence. The display behavior of still picture is defined as follows: Display of still picture shall be kept until display of next still picture or display reset given by navigation.

Frame-rate of still picture's video signal while being displayed is given by:

$$\text{Frame-rate} = \text{vui_time_scale} / \text{vui_num_units_in_tick}$$

where: vui_num_units_in_tick and vui_time_scale are provided in the vui_parameters of SPS that precedes a still picture.

3.5 Other constraints

For HDMV HEVC video stream, following constraints are applied.

3.5.1 Parameter limits

- Minimum size per one slice segment is 1 row of a coding tree block. A slice segment shall be composed of one or more rows of a coding tree block. A row of a coding tree block indicates all the coding tree blocks in a horizontal row of coding tree block.
- Maximum number of slice segments is 34.
- Maximum number of pictures which are stored in DPB is restricted in addition to the definition of MaxDpbSize in ITU-T Rec. H.265.
 - For 3840x2160: 6 (as defined in ITU-T Rec. H.265)
 - For 1920x1080: 6

3.5.2 Prohibited NAL unit

Following NAL units shall not be present.

- Coded slice segment of an BLA picture NAL unit (nal_unit_type= 16, 17 or 18)

3.5.3 STD delay

Maximum of STD delay is 1 second for video stream, 60 seconds for still picture.

3.5.4 Frame doubling/tripling

If frame doubling/tripling is used, picture structure shall be provided by the Picture Timing SEI message.

3.5.5 HRD conformance

HDMV HEVC video stream shall conform to Type 2 (NAL level) HRD conformance. The definition of Type2 HRD conformance is described in Annex C of the ITU-T Rec. H.265.

- It shall comply with output timing conformance.
- HRD conformance can be verified by using parameters provided in Buffering Period SEI and Picture Timing SEI. Or the PTS/DTS information in the MPEG-2 TS can also be used to obtain the timing instants to verify HRD conformance.

3.6 1920x1080 video format

This Section describes the coding constraints on 1920x1080 video format.

3.6.1 Sequence parameter set (SPS) for 1920x1080 video format

The allowed combinations of horizontal size of picture, vertical size of picture, Frame-rate derived from SPS are listed in Table 3-2.

Table 3-2 – Allowed combinations of parameters for 1920x1080 video format

horizontal size of frame	vertical size of frame	pic_width_in_luma_samples	pic_height_in_luma_samples	general_frame_only_constraint_flag	Frame-rate	progressive/interlace
1920	1080 (Note1)	1920	1080	1	60	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	60	progressive
1920	1080 (Note1)	1920	1080	1	59.94 (60000/1001)	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	59.94 (60000/1001)	progressive
1920	1080 (Note1)	1920	1080	1	50	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	50	progressive
1920	1080 (Note1)	1920	1080	1	25	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	25	progressive
1920	1080 (Note1)	1920	1080	1	24	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	24	progressive
1920	1080 (Note1)	1920	1080	1	23.976 (24000/1001)	progressive
1920	1080 (Note1)(Note2)	1920	1088	1	23.976 (24000/1001)	progressive

(Note1): The 1080 lines to be encoded or where decoded video should be placed vertically in the 1920x1080 video format are shown from line 42 to line 1121.

(Note2): 1088 is the height of the encoded luma component of frame pictures in lines.

aspect_ratio_idc: The aspect_ratio_idc shall be set to 1 (square sample).

bit_rate_scale, bit_rate_value_minus1: BitRate derived from these parameters shall indicate a value that is less than or equal to 100000000 bits/second.

cpb_size_scale, cpb_size_value_minus1: CpbSize derived from those parameters shall indicate a value that is less than or equal to 100000000 bits.

low_delay_hrd_flag: The low_delay_hrd_flag shall be set to 0.

Allowed combinations of the following parameters for 1920x1080 video format are listed in Table 3-3.

- aspect_ratio,
- horizontal size of frame, vertical size of frame, aspect_ratio_idc,
- general_frame_only_constraint_flag, conf_win_left_offset, conf_win_right_offset,
- conf_win_top_offset, conf_win_bottom_offset

Table 3-3 – Allowed combinations of parameters for 1920x1080 video format

aspect_ratio	SPS							
	pic_width_in_luma_samples	pic_height_in_luma_samples	aspect_ratio_idc	general_frame_only_constraint_flag	conf_win_left_offset	conf_win_right_offset	conf_win_top_offset	conf_win_bottom_offset
3 (16:9 aspect ratio)	1920	1080	1	1	0	0	0	0
	1920	1088	1	1	0	0	0	4

3.6.2 Colour description for 1920x1080 video format

colour primaries: The colour_primaries is set to 1 for ITU-R BT.709 for SDR, and 9 for ITU-R BT.2020^(Note) for SDR and HDR.

transfer_characteristics: The transfer_characteristics shall be set to 1 for ITU-R BT.709, and 14 for ITU-R BT.2020^(Note) for SDR. This value shall be set to 16 for HDR.

matrix_coeffs: The matrix_coeffs is set to 1 for ITU-R BT.709 for SDR, and 9 for ITU-R BT.2020^(Note) for SDR and HDR.

(Note): As for BT.2020, non-constant luminance shall be used.

If the video_signal_type_present_flag is set to 1, the video_full_range_flag shall be set to 0.

3.6.3 Location of chroma samples

For ITU-R BT.709 (colour primaries is set to 1), chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall be set to 0 or 2 if chroma_loc_info_present_flag is set to 1. If chroma_loc_info_present_flag is set to 0, the location of chroma sample is type 0 and chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field are both inferred to be equal to 0.

For ITU-R BT.2020 (colour primaries is set to 9), chroma_loc_info_present_flag shall be set to 1 and chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall be set to 2.

chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall have the same value.

3.7 3840x2160 video format

This Section describes the coding constraints on 3840x2160 video format.

3.7.1 Sequence parameter set (SPS) for 3840x2160 video format

The allowed combinations of horizontal size of picture, vertical size of picture, Frame-rate derived from SPS are listed in Table 3-4.

Table 3-4 – Allowed combinations of parameters for 3840x2160 video format

horizontal size of frame	vertical size of frame	pic_width_in_luma_samples	pic_height_in_luma_samples	general_frame_only_constraint_flag	Frame-rate	progressive/interlace
3840	2160	3840	2160	1	60	progressive
3840	2160	3840	2160	1	59.94 (60000/1001)	progressive
3840	2160	3840	2160	1	50	progressive
3840	2160	3840	2160	1	25	progressive
3840	2160	3840	2160	1	24	progressive
3840	2160	3840	2160	1	23.976 (24000/1001)	progressive

aspect_ratio_idc: The aspect_ratio_idc shall be set to 1 (square sample).

bit_rate_scale, bit_rate_value_minus1: BitRate derived from these parameters shall indicate a value that is less than or equal to 100000000 bits/second.

cpb_size_scale, cpb_size_value_minus1: CpbSize derived from those parameters shall indicate a value that is less than or equal to 100000000 bits.

low_delay_hrd_flag: The low_delay_hrd_flag shall be set to 0.

Allowed combinations of the following parameters for 3840x2160 video format are listed in Table 3-5.

- aspect_ratio,
- horizontal size of frame, vertical size of frame, aspect_ratio_idc,
- general_frame_only_constraint_flag, conf_win_left_offset, conf_win_right_offset,
- conf_win_top_offset, conf_win_bottom_offset

Table 3-5 – Allowed combinations of parameters for 3840x2160 video format

aspect_ratio	SPS							
	horizontal size of frame	vertical size of frame	aspect_ratio_idc	general_frame_only_constraint_flag	conf_win_left_offset	conf_win_right_offset	conf_win_top_offset	conf_win_bottom_offset
3 (16:9 aspect ratio)	3840	2160	1	1	0	0	0	0

3.7.2 Colour description for 3840x2160 video format

colour primaries: The colour_primaries is set to 1 for ITU-R BT.709 for SDR, and 9 for ITU-R BT.2020^(Note) for SDR and HDR.

transfer_characteristics: The transfer_characteristics shall be set to 1 for ITU-R BT.709, and 14 for ITU-R BT.2020^(Note) for SDR. This value shall be set to 16 for HDR.

matrix_coeffs: The matrix_coeffs is set to 1 for ITU-R BT.709 for SDR, and 9 for ITU-R BT.2020^(Note) for SDR and HDR.

(Note): As for BT.2020, non-constant luminance shall be used.

If the video_signal_type_present_flag is set to 1, the *video_full_range_flag* shall be set to 0.

3.7.3 Location of chroma samples

For ITU-R BT.709 (colour primaries is set to 1), chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall be set to 0 or 2 if chroma_loc_info_present_flag is set to 1. If chroma_loc_info_present_flag is set to 0, the location of chroma sample is type 0 and chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field are both inferred to be equal to 0.

For ITU-R BT.2020 (colour primaries is set to 9), chroma_loc_info_present_flag shall be set to 1 and chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall be set to 2.

chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field shall have the same value.

3.8 HDR video format

Dynamic range of video is defined as the difference between the brightest whites and the darkest blacks in the image. HDR (High Dynamic Range) increases maximum luminance to reproduce bright images such as sunlight, reflections. Increased maximum luminance allows reproduction of images with higher contrast than traditional SDR (Standard Dynamic Range) images in which maximum luminance has typically been set up to 100 cd/m².

The BD-ROM specification defines BDMV HDR video formats. The BDMV HDR is the HDR video format which is mandatory for player in the BD-ROM specification.

3.8.1 BDMV HDR

The BDMV HDR is characterized by the following constraints.

- BDMV HDR video stream shall be HDMV HEVC video stream specified in ITU-T Rec. H.265.
- colour primaries shall be BT.2020 with non-constant luminance.
- transfer_characteristics shall be SMPTE 2084 EOTF.

3.9 SDR video format

The SDR video format is characterized by the following constraints.

- SDR video stream shall be HDMV MPEG-4 AVC video stream or HDMV HEVC video stream.
- colour primaries shall be BT.709 or BT.2020 with non-constant luminance for HDMV HEVC video stream and shall be BT.709 for HDMV MPEG-4 AVC video stream.
- transfer_characteristics in VUI parameters shall be set to 1 for ITU-R BT.709, and 14 for ITU-R BT.2020.

3.10 Allowed combination of video attributes for HDMV HEVC video stream

This section describes video attributes (resolution, colour primaries, transfer characteristics, and bit depth) for HDMV HEVC video streams. Allowed combinations of video attributes are defined in Table 3-6.

Table 3-6 – Allowed combinations of resolution, transfer_characteristics and bit-depth for HDMV HEVC video streams

horizontal size of frame	vertical size of frame	colour_primaries	transfer_ch aracteristics	bit depth	content type
1920	1080	1 (BT.709)	1	10	SDR
1920	1080	9 (BT.2020)	14	10	SDR
1920	1080	9 (BT.2020)	16 (ST 2084)	10	BDMV HDR
3840	2160	1 (BT.709)	1	10	SDR
3840	2160	9 (BT.2020)	14	10	SDR
3840	2160	9 (BT.2020)	16 (ST 2084)	10	BDMV HDR

3.11 HEVC video stream decoder model

In case an input to TB (Transport buffer) is an HEVC video stream, the BDAV-STD decodes the input in the same way as T-STD defined in ISO/IEC 13818-1. For transferring the HEVC video stream data from MB (Multiplexing buffer) to EB (Elementary stream buffer), ISO/IEC 13818-1 defines two methods: the leak method and HRD. It is restricted that the BDAV-STD shall use the leak method for transferring the HEVC video stream data from MB to EB. (The BDAV-STD shall not use the HRD for the transfer of data from MB to EB).

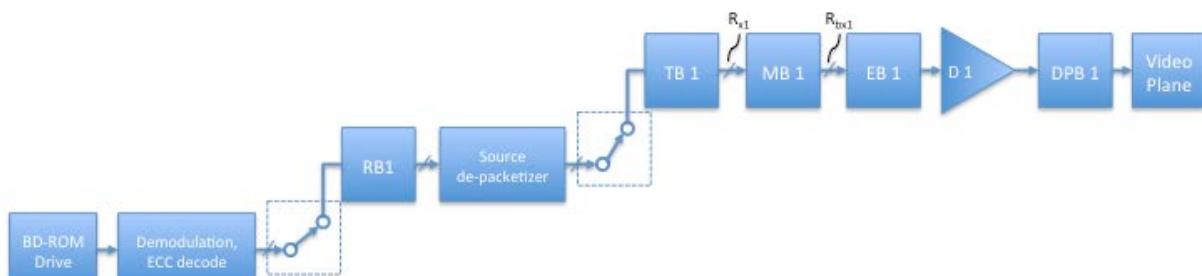


Figure 3-6 – BDAV-STD Video Decoder Model

3.11.1 BDAV-STD model parameter limits

This parameter limits for BDAV-STD model for the HEVC video stream decoder are defined in Table 3-7

Table 3-7 – Parameter limits for BDAV-STD model for HEVC video stream

Notation	Meaning	
R _{x1}	Leak rate from TB1 for HEVC video stream	1.1*100*10 ⁶ [bits/second]
R _{bx1}	Leak rate from MB1 for HEVC video stream	1.0*100*10 ⁶ [bits/second]
MB1	Multiplexing buffer for HEVC stream	73333 [bytes]
EB1	Elementary stream buffer for HEVC stream	12500000 [bytes]
DPB1	Decoded picture buffer for HEVC stream	93312000 [bytes]

3.12 HEVC video streams constraints for seamless connection

- 1) The following conditions shall not change in the HEVC video streams in Clip AV streams (TS1 and TS2) with seamless connection.
 - general_profile_idc
 - general_tier_flag
 - general_level_idc
 - pic_width_in_luma_samples
 - pic_height_in_luma_samples
 - aspect_ratio_idc
 - Frame-rate = vui_time_scale / vui_num_units_in_tick
 - BitRate[cpb_cnt_minus1], which is derived from bit_rate_scale and bit_rate_value_minus1.
 - CpbSize[cpb_cnt_minus1], which is derived from cpb_size_scale and cpb_size_value_minus1.
 - colour primaries
 - transfer_characteristics
 - matrix_coeffs
- 2) Video data in TS1 shall terminate with end of sequence (end_of_sequence_rbsp()).
- 3) Video data in TS2 shall start with VPS, SPS, PPS(s), and an IDR picture.
- 4) The video presentation units (frame) defined in the bit-stream shall be continuous across the connection. There shall be neither gap nor overlap in the presentation at the connection.
- 5) The video access units defined in the bit-stream shall be continuous across the connection. There shall be neither gap nor overlap in the decoding process at the connection.
- 6) The decoding delay of TS1 shall be the same as the decoding delay of TS2. Here, “decoding delay means the PTS of the first presented picture in a GOP minus the DTS of the first decoded picture in the GOP.